This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

ESTABLISHED WORKS OF GENERAL INTEREST.

HISTORICAL WORKS.

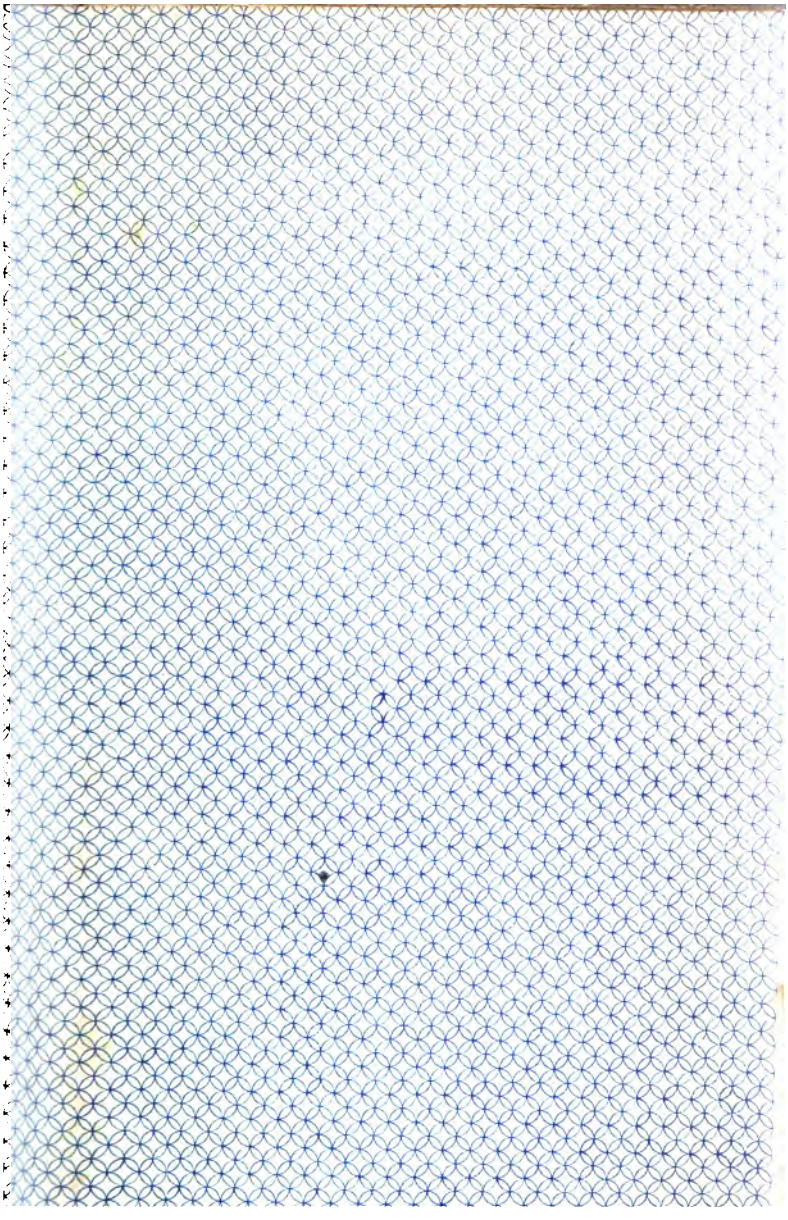
Sir Walter Scott's History of Scotland	2 vols. 12s.
Thomas Moore's History of Ireland	4 vols. 24s.
The History of England, by Mackintosh, Bell, & Wallace	10 vols. 60s.
The History of France, by Crowe	3 vols. 18s.
The History of the United States, by Fergus	2 vols. 12s.
The History of Russia, by Bell	3 vols. 18s.
The History of Poland, by Dunham	1 vol. 6s.
The History of the Netherlands, by Grattan	1 vol. 6s.
The History of Switzerland	1 vol. 6s.
History of Denmark, Sweden, & Norway, by Dunham,	3 vols. 18s.
The History of the Germanic Empire, by Dunham	3 vols. 18s.
The History of the Italian Republics, by Sismondi	1 vol. 6s.
The History of Spain and Portugal, by Dunham	5 vols. 30s.
The History of the Middle Ages, by Dunham	4 vols. 24s.
Bishop Thirlwall's History of Greece	8 vols. 48s.
The History of Rome	2 vols. 12s.
The Fall of the Roman Empire, by Sismondi	2 vols. 12s.
Grecian and Roman Antiquities, by Fosbroke, &c.	2 vols. 12s.
The Chronology of History, by Sir H. Nicolas	1 vol. 6s.
Outlines of History, by Keightley	1 vol. 6s.
The History of the Reformation, by Stebbing	2 vols. 12s.
The History of the Church, by Stebbing	2 vols. 12s.
The History of Maritime & Inland Discovery, by Cooley	3 vols. 18s.

BIOGRAPHICAL WORKS.

The Statesmen of the Commonwealth, by Forster	5 vols. 30s.
Lives of British Statesmen, by Forster, &c.	7 vols. 42s.
**** This work includes the former.	
Gleig's Lives of British Commanders	3 vols. 18s.
Southey's Lives of British Admirals	5 vols. 30s.
Lives of British Poets, by Robert Bell	2 vols. 12s.
Roscoe's Lives of British Lawyers	1 vol. 6s.
Lives of British Dramatists, by Dunham, &c.	2 vols. 12s.
Lives of Early British Writers, by Dunham	1 vol. 6s.
James's Lives of Foreign Statesmen	5 vols. 30s.
The most eminent French Authors, by Mrs. Shelley, &c.	2 vols. 12s.
Lives of Spanish, Italian, & Portuguese Authors, by do.	3 vols. 18s.

The above works are comprised in
THE CABINET CYCLOPÆDIA, now completed in 133 vols. £39. 10s.

LONDON: [illegible] AND CO.: AND JOHN TAYLOR.



SCHOOL

CHEMISTRY:

OR,

PRACTICAL RUDIMENTS OF THE SCIENCE.

BY

ROBERT DUNDAS THOMSON, M.D.

MASTER IN SURGERY OF THE UNIVERSITY OF GLASGOW,
LECTURER ON CHEMISTRY IN THE SAME UNIVERSITY,
AND FORMERLY IN THE MEDICAL SERVICE OF THE HONOURABLE
EAST INDIA COMPANY.

LONDON:

PRINTED FOR

LONGMAN, BROWN, GREEN, AND LONGMANS,

PATERNOSTER-ROW.

1848.

193. g. 115.

LONDON:
SPOTTISWOODE and SHAW,
New-street-Square.

PREFACE.

It has been said by Bergmann, that Natural History, or the study of animals, plants, and minerals, teaches us the elementary rudiments or alphabet of the great book of nature; Natural Philosophy instructs us in spelling; and Chemistry in reading distinctly. To serve as an introduction to such an important science generally, and also to extend a knowledge of its practical elements among those who influence the studies of the rising generation, are the objects of the present publication. The Natural Philosophy of the last century included, not only what is taught at the present day under that title, but likewise Chemistry and Astronomy. The two latter have now become distinct sciences, but they no longer, as they formerly did, constitute part of the usual studies of the clerical and scholastic professions; although the phenomena of which Chemistry treats are of the most familiar occurrence, and many of the laws which it developes of constant domestic application. These, too, afford easily appreciable proofs of design. But if we desire examples of a more sublime nature, we have only to consult the details of Inorganic Chemistry, constituting

the first part of the volume, to find evidence that the ultimate particles of matter, so minute as to weigh less than the billionth part of a grain, have been impressed with unvarying laws, and adjusted with skill so admirable, as to impel us to the literal conclusion of the sacred writer, that the Divine Being has "comprehended the dust of the earth in a measure, weighed the mountains in scales, and the hills in a balance."

When we turn to Vegetable Chemistry, we learn that the same materials with which we become intimate in the mineral world, in one perpetual round, serve for the support and nourishment of all the plants which subsist upon the face of the globe. But the vegetable world, consisting merely of matter endowed with the power of nourishing itself, and without any nerves or sensibility, must be viewed as the garden of those beings to whom we afterwards proceed, where sense and intellect, in all their efficiency, discover the image of a Mighty Creator.

Much difficulty has been experienced in commencing the study of Chemistry from the novelty of the names, which, as in a new language, appear overwhelming. It has appeared to the author that this objection may in some measure be overcome by introducing the student practically to an acquaintance with the science, and thus to place its mode of acquisition upon a somewhat similar basis to that of botany or languages. Suppose, for example, a metal is placed

in the hands of one unacquainted with the science, he is directed to attend to its colour, to determine its specific gravity, &c. as explained in the first chapter of the work, to ascertain the effect of acids upon it, to test the solution of the metal in the acid by the tables in the second chapter, and the characters before the blowpipe of the matter which remains when a part of the acid solution is evaporated, as given in the same chapter. All these data are entered in a note book, with the conclusions which the student has drawn with respect to the nature of the metal subjected to his examination; and thus he is initiated into an acquaintance with the language of the science, and with inductive reasoning. The salts of the various metals may also be examined in a similar way. A teacher should therefore have in his possession the common metals, such as iron, copper, zinc, lead, tin, mercury, &c., and instruct the pupil to prove their nature by physical and chemical tests; even young boys will be found to engage in such inquiries with great spirit and energy. The teacher should also possess sets of the metallic and other salts, and give them out to be examined by the test tables; first singly, and when the pupil has become familiar with the oxides and sulphurets to which the test tables principally refer, and the distinguishing tests, he may have mixtures of two salts, and afterwards of three salts, &c., submitted to his examination. An hour or more in the day, according to circumstances, may be

devoted to such exercises, which tend to familiarise the pupil with the habit of observation, and with words. Another period, however, is to be set apart for the study of the principles of the science. The pupils are to be arranged round a table, in companies of two or three, with the necessary apparatus before them.* The teacher, commencing at Chapter III., is to read or describe the theory of the mode of forming oxygen and the other gases onwards, and then the pupils are to make the gas, and ascertain its properties as described. At the same time, they should become familiarised on the black board with the mode of writing formulæ, and be made thoroughly to understand the source of the gases evolved, and the nature of the compounds from which they are obtained. In the earlier part of the work diagrams are given, so as to render the subject clear to the beginner; and these may be followed out on the board as the course of lessons proceeds, although given in the work in another form. After the gases are discussed, the alkalies, earths, and metals come under consideration, and many of their important compounds may be formed, such, more particularly, as are employed for useful purposes. Under Vegetable Chemistry, in Chapter VI., the various parts of plants may be examined with the assistance of the microscope, and their chemical

* Cheap apparatus of British or foreign glass, &c. may be obtained from Messrs. Griffin, Baker Street, London, and Buchanan Street, Glasgow.

constitution studied, while the processes of bleaching, dyeing, fermenting, &c. may be repeated. Flour and potatoes should be analysed, so as to prepare the pupil for understanding the uses of the several parts of the food in Animal Chemistry, in Chap. VII., which is principally devoted to the changes which the food, originally derived from plants, undergoes when swallowed by animals.

This work being intended also as an Introduction, in the College of Glasgow, (the first portion having been long familiar to the students,) to the System of Chemistry by Dr. Thomas Thomson, some parts have been printed in a smaller type, in order that it may include a tolerably complete sketch of the science.

GLASGOW COLLEGE,
Sept. 1848.

CONTENTS.

Page

INTRODUCTION - - - - - - 1

Table of Atomic Weights of Elements - - 2

CHAPTER I.

MODE OF DETERMINING THE PHYSICAL OR EXTERNAL CHARACTERS OF BODIES - - - - 4

Colour, Hardness, Taste, Smell, and Solubility of Bodies - - - - - 4, 5

Crystalline Form of Bodies - - - 5, 6

Mode of determining Specific Gravities - - 7

CHAPTER II.

OF THE INTERNAL OR CHEMICAL PROPERTIES OF BODIES 14

Action of the Blowpipe on Bodies - - 14

Action upon Bodies *per se* - - - 15

Colours and Odour produced before the Blowpipe - 15, 16

Blowpipe Action on Charcoal - - - 16

Blowpipe Action with Carbonate of Soda - - 16

Ditto, with Borax and Salt of Phosphorus - 17

Testing Tables and testing Analyses - - 18

Table of Tests for Acids - - - 22

Table I. Tests for Bases — Caustic Ammonia - 24

Table II. Ditto: Caustic Soda or Potash - 25

Table III. Ditto: Sulphohydric Acid - - 26

Table IV. Ditto: Sulphohydret of Ammonia - 27

Distinguishing Tests for Bases - - - 28

CHAPTER III.

Page

SALT RADICALS. — SUBSTITUTIONAL BODIES - - 31

Oxygen - - - - - - 32
Preparation of Gases in general - - - 32
Chlorine and Compounds - - - - 41
Iodine and ditto - - - - - 44
Bromine and ditto - - - - - 45
Fluorine and ditto - - - - - 46

CHAPTER IV.

ACID RADICALS - - - - - 47

Hydrogen and Compounds - - - 47
Water - - - - - - 54
Chlorohydric or Muriatic Acid - - - 58
Nitrogen - - - - - - 61
Common Air - - - - - 62
Protoxide of Nitrogen, or Laughing Gas - - 64
Deutoxide or Binoxide of Nitrogen - - 65
Ternitrous or Nitrous Acid - - - 66
Quaternitrous or Hyponitric Acid - - 67
Nitric Acid - - - - - 67
Ammonia or Hartshorn - - - - 70
Carbon - - - - - - 73
Carbonic Acid - - - - - 74
Carbonic Oxide - - - - - 77
Oxalic Acid - - - - - 78
Carburetted Hydrogen - - - - 79
Olefiant Gas - - - - - 80
Coal Gas - - - - - 81
Cyanogen - - - - - - 81
Cyanic Acid - - - - - 82
Urea - - - - - - 82
Fulminic and Cyanuric Acids - - - 82
Cyanohydric or Prussic Acid, and Cyanide of Potassium - - - - - 83
Yellow Prussiate of Potash and Prussian Blue - 84
Compounds of Cyanogen, Alloxan, &c. - - 85
Boron - - - - - - 86
Silicon - - - - - - 86
Silica, and its Varieties, — Flint, Quarts, &c. - 86
Glass, and Fluosilicic Acid - - - 88
Phosphorus and Acids - - - - 89, 90

Page

Phosphuretted Hydrogen - - - - 91
Sulphur or Brimstone - - - - 92
Sulphuric Acid, or Oil of Vitriol - - - 93
Sulphohydric Acid or Sulphuretted Hydrogen - 96
Selenium. Tellurium - - - - 97
Arsenic and Arsenious Acid - - - 98
Arsenic Acid, Chloride, and Sulphurets - - 101
Antimony - - - - - - 101
Tartar Emetic - - - - - 102
Chromium. Oxides and Chromic Acid - - 103
Vanadium - - - - - 104
Uranium and *Molybdenum* - - - - 105
Tungsten, Columbium, Niobium, and *Pelopium* - 106
Titanium. Norium - - - - 107

CHAPTER V.

BASIC RADICALS. CLASS I. ALKALINE BASES. *Potassium* 108

Solution of Caustic Potash - - - 109
Iodide of Potassium. Salts of Potash - - 111
Nitre, Gunpowder, Squibs, Glass - - 111, 112
Sodium - - - - - - 113
Caustic Soda - - - - - 113
Common Salt, Carbonate of Soda, and Salts - 114
Lithium - - - - - - 116

BASIC RADICALS. CLASS II. METALS OF ALKALINE EARTHS - - - - - - 117

Barium. Oxides and Salts - - - 117
Strontium. Oxides and Salts - - - 118
Calcium. Lime - - - - - 119
Bleaching Powder - - - - 121
Carbonate, Sulphate of Lime and Salts - 122, 123
Magnesium. Magnesia - - - - 123
Salts of Magnesia - - - - 124

BASIC RADICALS. CLASS III. METALS OF EARTHS PROPER 126

Aluminum and Alumina - - - - 126
Alum and Porcelain - - - - 127
Glucinum, Zirconium, Thorium, Yttrium, &c. - 128

	Page
BASIC RADICALS. CLASS IV. DIFFICULTLY FUSIBLE METALS - - - - -	129
Iron and Steel . - - - -	129
Oxides and Salts - - - - -	131
Manganese - - - - -	132
Oxides and Salts - - - - -	133
Nickel - - - - - -	134
Cobalt and Oxides - - - -	135
Copper and Oxides - - - -	136
Silver and Oxide - - - - -	138
BASIC RADICALS. CLASS V. EASILY FUSIBLE METALS -	140
Zinc and Oxide - - - - -	140
Cadmium - - - - -	141
Lead - - - - - -	141
Tin - - - - - -	144
Bismuth - - - - - -	146
Mercury - - - - - -	146
BASIC RADICALS. CLASS VI. NOBLE METALS - -	150
Gold - - - - - -	150
Platinum - - - - - -	152
Palladium. Rhodium. Iridium - - -	153
Osmium. Ruthenium - - - -	154

CHAPTER VI.

ORGANIC CHEMISTRY. VEGETABLES - - -	155
I. SUBSTANCES FORMING THE CELLS: CELLULIN, LIGNIN	158
II. STARCHY SUBSTANCES IN THE CELLS, AND ALLIED BODIES - - - - - -	163
Analysis of Flour, Potatoes - - -	165
III. SUBSTANCES IN THE JUICES OF PLANTS - -	168
Gums and Pectic Acid - - - -	168
Sugars - - - - - -	169
Liquorice. Manna. Lactic Acid - -	170
Changes in Sugar. Alcohol - - -	171
Beer. Wine. Spirits - - - -	172
Bread-making - - - - -	173
Ethers - - - - - -	174

Page

Acetous or Vinegar Fermentation - - 175
Aldehyde. Acetic Acid or Vinegar - - 176
Acetone. Cacodyle - - - - 177
Potatoes' Spirit, or Amyle Series - - - 178

IV. Other Secretions of Plants and allied Bodies 179
Benzoyle Series. Amygdalin. Emulsin - - 179
Salicyle Series - - - - - 181
Cinnamyle Series - - - - 181
Glyceryle. Acryle. Cetyle - - - 182
Vegetable Alkaloids - - - - 183
Nicotin to Coniin - - - - 183
Quinin. Cinchonin. Aricin - - - 184
Morphin. Codein - - - - 185
Veratrin, Strychnin, &c. - - - - 186
Brucin, Bebeerin, Piperin, &c. - - - 187
Caffein or Thein, Cyaniline, &c. - - - 188
Extractive and Bitter Principles, &c. - - 188
Absinthin to Melampyrin - - - 189
Mudarin to Xanthopicrin - - - 190
Colouring Matters secreted in Plants - - 190
Red Colours. Madder - - - - 191
Archil, Compounds from - - - 192
Logwood. Safflower. Carmine - - - 193
Blue Colours: Indigo - - - - 193
Compounds of Indigo - - - - 194
Litmus. Yellow Colours - - - 196
Acids secreted by Plants. Tartaric Acid - - 197
Racemic, Malic, Citric, and Tannic Acids - 198
Meconic and Kinic Acids - - - 199
Oils, Fats, and Oily Acids from Plants - - 200
Stearic and Margaric Acids. Soap-making - 201
Suberic, Succinic, and Oleic Acids - - 202
Pimelic, Adipic, Lipic, and Butter Acids - 203
Palmitic, Camphoric, and other Acids - - 204
Wax. Essential Oils - - - - 205

V. Excretions of Plants. Resins. Gum Resins - 205

CHAPTER VII.

Animal Chemistry - - - - - 207

1. *Mastication.* Teeth, Bones, Saliva - 207, 208

2. *Primary Digestion* - - - - 209
Bile, — its Composition and Derivatives - - 210

Page

3. *Sanguification, or Formation of Blood* - - 212
Composition of the Blood - - - 213

4. *Nutrition* - - - - - 213
Brain and Muscle - - - - 214

5. *Secretion of Substances from the Blood.* Milk - 216
Analysis of Milk. Urine - - - 217
Calculi, and Mode of Testing - - 217, 218
Analysis of Urine - - - - 218

6. *Respiration and Skin Exhalation* - - 219
Destination of the Food - - - 219
Law of the Balance of the Food - - - 220
Causes of Disease - - - - 221

EXPLANATION OF CHEMICAL TERMS - - - 223

APPENDIX. Tables of the Strength of Acids, Ammonia, and Alcohol - - - - 229

INDEX - - - - 230

ERRATA.

Page 18. line 23., for "solution" read "portion."
23. line 12. from bottom, for "NH_3-Cl" read "NH_3HCl."
32. line 20., for "*Oxone*" read "*Ozone*."
47. line 12. from bottom, for "γνομαι" read "γεινομαι."
61. line 2., erase "à."
136. line 13., for "homomorphous" read "isomorphous."

GOVERNMENT EXPERIMENTS ON FEEDING CATTLE.

Just published, in fcp. 8vo. price 5s. cloth,

EXPERIMENTAL RESEARCHES on the FOOD of ANIMALS and the FATTENING of CATTLE: with Remarks on the Food of Man. By ROBERT DUNDAS THOMSON, M.D., of the University of Glasgow.

"A very elaborate and useful work on the subject of which it treats."
Bell's Messenger.

"The question of the origin of the fat of animals appears to be completely resolved by these beautiful and elaborate experiments." — *Baron Liebig.*

"In this little work we have a very explicit and intelligible account of a long series of experiments made at the instance of the Government, together with some general principles of great practical importance deduced from them by the author." — *Spectator.*

"We would direct the attention of our readers to this little work, not merely as it contains a full report of the experiments already referred to in our pages, which its author undertook on malt, barley, and other substances, as food for cattle, but also as it contains a general view of the subjects of food and digestion, which it is of the greatest importance for farmers to be acquainted with." — *Gardeners' Chronicle.*

LONDON: LONGMAN, BROWN, GREEN, & LONGMANS.

INTRODUCTION

TO THE

RUDIMENTS OF CHEMISTRY.

INTRODUCTION.

THE material world, or all that *we see* around us, consists, according to our present knowledge, of sixty-two different kinds or species of matter, termed *elements*. The particles of which each species or element is composed are supposed to be hard round bodies, or atoms which cannot be divided or broken. The same kinds of particles have a tendency to adhere to each other, by what is termed the *attraction of cohesion*; thus sugar not only exists in the state of powder, but in lumps, masses, or crystals. But besides this *aggregation*, one species of particles has an affinity for another kind; as when iron is exposed to moist air it becomes covered with rust, in consequence of the union of the *particles* of the oxygen of the air with the particles of the iron by the power of *chemical affinity*. Now, *chemistry may be defined generally to be that science which teaches the characters of the sixty-two forms of matter, and their action upon each other*. The result of this action is an infinite variety of *chemical compounds*, as oxides, acids, salts, neutral bodies, &c. The particles or atoms of each kind of matter do not alter in weight or size, but are invariably the same; so that a definite or combining weight is attached to them, which is termed the *atomic* or *equivalent weight*. Thus the weight of the atom or ultimate particle of iron is $3\frac{1}{2}$, and that of sulphur 2. When these bodies unite, they form $5\frac{1}{2}$ sulphuret of iron (FeS). But they can also unite in another proportion, viz., one atom or particle of iron with two particles or atoms of sulphur; they then form the bisulphuret of iron (FeS_2), the compound particle or atom of which weighs $7\frac{1}{2}$. Chemical bodies, both simple and compound, are either *amorphous* (privative α and $\mu o \rho \phi \eta$, shape, destitute of shape),

as clay, or *crystallized*, as Epsom salt and common salt. Sometimes in crystals one of the elements may be replaced by another element without changing the form of the crystal, as with phosphorus and arsenic compounds. The atoms of such elements are supposed to have the same size and shape, and are called *ise-* or *isomorphous* (*ισο*η and *μορφη*, similar shape). When two compounds have different properties, but the elements present in the same proportion, they are said to be *isomeric* (*ισον*, *μερος*, similar part).

TABLE OF ATOMIC WEIGHTS OF ELEMENTS.

Names of the Elements. Those in Italics are rare.	Symbols.	Oxygen = 1	Hydrogen = 1
I. SALT FORMING RADICALS; OR,			
Substitutional Bodies: —			
Oxygen,* - - -	O	1·	8
Chlorine, - - -	Cl	4·5	36
Iodine, - - -	I	15·75	126
Bromine, - - -	Br	9·75	78
Fluorine, - - -	Fl	2·25	18
II. ACID RADICALS.			
Non-Metallic: —			
Hydrogen, - - -	H	0·125	1
Nitrogen, (Azote) - -	N or Az	1·75	14
Carbon, - - - -	C	0·75	6
Boron, - - - -	B	1·25	10
Silicon, - - - -	Si	1·	8
Phosphorus, - - -	P	4·	32
Sulphur, - - -	S	2·	16
Selenium, - - -	Se	5·	40
Metallic: —			
Arsenic, - - -	As	9·5	76
Antimony, (Stibium) -	Sb	16·	128
Tellurium, - - -	Te	8·	64
Chromium, - - -	Cr	3·5	28
Vanadium, - - -	V	8·5	68
Uranium, - - -	U	7·5	60
Molybdenum, - - -	Mo	6·	48
Tungsten, (Wolfram) -	Tn or W	11·75	94
Titanium, - - -	Ti	3·	24
Columbium, (Tantalum) -	Cm or Ta	23·	184
Niobium. - - -	No	?	?
Pelopium, - - -	Pe	?	?
Norium? - - -	Nr	?	?

* Is placed here from its substitutional character.

Names of the Elements. Those in Italics are rare.	Symbols.	Oxygen = 1	Hydrogen = 1
III. BASIC RADICALS.			
Alkalies (Metals of):—			
Potassium, (Kalium)	K	5·	40
Sodium, (Natrium)	Na	3·	24
Lithium,	L	0·75	6
Alkaline Earths (Metals of):—			
Calcium, (Lime)	Ca	2·5	20
Barium,	Ba	8·5	68
Strontium,	Sr	5·5	44
Magnesium,	Mg	1·5	12
Earths (Metals of):—			
Aluminum,	Al	1·75	14
Glucinum,	G	3·25	26
Zirconium,	Zr	4·25	34
Thorium,	Th	7·5	60
Didymium?	D	?	?
Lantanum,	Ln	6·	48
Cerium	Ce	5·75	46
Yttrium,	Y	4·	32
Terbium?	Tb	?	?
Erbium?	E	?	?
Difficultly Fusible Metals:—			
Iron, (Ferrum)	Fe	3·5	28
Manganese,	Mn	3·5	28
Nickel,	Ni	3·75	30
Cobalt,	Co	3·75	30
Copper, (Cuprum)	Cu	4·	32
Silver, (Argentum)	Ag	13·5	108
Easily Fusible Metals:—			
Zinc,	Zn	4·125	33
Cadmium,	Cd	7·	56
Lead, (Plumbum)	Pb	13·	104
Tin, (Stannum)	Sn	7·25	58
Bismuth,	Bi	13·5	108
Mercury, (Hydrargyrum)	Hg	12·5	100
Noble Metals:—			
Gold, (Aurum)	Au	12·5	100
Platinum,	Pt	12·25	98
Palladium	Pd	6·75	54
Rhodium,	R	6·5	52
Osmium,	Os	12·5	100
Iridium,	Ir	12·25	98
Ruthenium,	Ru	6·5	52

CHAPTER I.

MODE OF DETERMINING THE PHYSICAL OR EXTERNAL CHARACTERS OF BODIES.

In examining the chemical properties of substances, there are several characters which may be investigated without much comparative manipulation. The principal of these are, 1. The *colour* of the body. 2. Its *hardness*, compared with other substances. 3. Its *taste*. 4. Its *smell*. 5. The effects of *heat* upon it ascertained by exposing it on a spatula, or a knife, to the flame of a lamp, if in the solid form; and in a tube, if the body should exist in the fluid state. 6. Its solubility in *water*, *mineral acids*, *alcohol*, and *ether*. 7. The action of the solution upon litmus paper. 8. Its *crystalline* form. 9. Its *peculiar* weight, compared to an equal bulk of water, usually termed its specific gravity.

1. The colour of bodies is often an important index to their nature, especially in the study of the metals. The salts of soda, potash, the other alkalies and earths, are generally colourless or white, for example; while those of iron are *green*, *black*, or *red*; those of manganese, *flesh red*; of nickel, *green*; of copper, *blue*, and *green* under particular circumstances; of chromium, and protoxide of uranium, of iron, of nickel, *green*.

2. The hardness of a body is of most importance in reference to minerals. The following is the comparative scale employed for determining this property: —

1. Talc.
2. Rock salt, gypsum.
3. Calcareous spar.
4. Fluor spar.
5. Phosphate of lime.
6. Felspar.
7. Rock crystal.
8. Topaz.
9. Corundum.
10. Diamond.

The first substance in the table is the softest, and the last the hardest. If we find that the substance we are examining scratches talc, but does not affect rock-salt, we say its hardness is 1·5 (1½), or some intermediate fraction, of which we judge by the comparative hardness. Sometimes the finger-nail affords an approximation to the hardness of a substance. Thus, sulphate of lime (gypsum), or plaster of Paris, is scratched easily with the nail, while only a trifling effect is produced on calcareous spar.

3. The taste enables us to distinguish *sour* or *acid* bodies, as oxalic acid, cream of tartar; *sweet*, as salts of glucina; *bitter*, as Epsom salts; *saline*, or *salt*, as common salt. By taste we can thus distinguish between oxalic acid and Epsom salt — two bodies

which are sometimes confounded. Chemists should therefore familiarize themselves with the taste of bodies.

4. The organ of *smell* is an important auxiliary to the chemist. By means of the sense of smell we can often detect most minute quantities of ammonia, nitric acid, &c., when chemical tests would fail to afford any result to be depended on.

5. By applying *heat*, we judge of the fixed or volatile nature of a body; by the presence of nitrogen in it, when it emits an odour of feathers or burned animal matter — that peculiar smell from which we judge that a woollen rag has been burned. For example, if we expose sugar or starch to the action of a flame, this peculiar odour is not perceptible; but if we burn horn or hair, it is at once obvious to the sense of smell.

6. The *solubility* of salts is an important character. The insolubility of stony minerals in water is a characteristic property of these products of the mineral kingdom. Almost all the alkaline oxygen salts are soluble in water, and many of the metallic salts are in a similar condition. When salts are insoluble, we take advantage of this property to effect their separation from other bodies in solution. When a substance dissolves in a mineral acid (sulphuric, nitric, or muriatic) with effervescence, that is, the disengagement of carbonic acid, we infer that it is a carbonate. A certain number of stony minerals, containing from five to ten per cent. and upwards of water, are decomposed by muriatic and nitric acids, but the greater bulk of minerals, having silica as their acid, are comparatively unaffected by these agents.

By the use of alcohol we can often separate bodies when both are soluble in water; for example, flour contains sugar and gum, both of which bodies dissolve in water; but by adding boiling alcohol to their solution, the gum is precipitated, while the sugar remains dissolved in the alcoholic fluid.

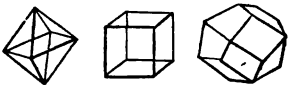
Some substances are soluble, while others are insoluble, in ether. Thus, the cholesterin of the nerves and brain is soluble in ether, while the acid of the same organs (cerebric acid) is scarcely soluble in that fluid. We are thus enabled to separate them.

7. The *crystalline* form, in opposition to an amorphous mass, is a valuable index in many cases. The taste and crystalline form enable us to distinguish oxalic acid (a poison) from sulphate of magnesia, or Epsom salt, an important medicine. The following are their characters: —

	Taste.	*Crystal.*
Oxalic acid -	Sour	Four-sided, oblique prism
Epsom salt -	Bitter	Four-sided, nearly rectangular.

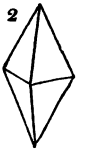
The crystalline forms which substances assume are all reducible to six classes and their modifications. I. The first class is the *regular* or *octahedral system*, in which there are three axes or lines joining the angles, which are all equal. To this belong the octahedron and cube. As illustrations, we have *alum* as an octahedron, *common salt* as a cube, *garnet* as a dodecahedron.

1 1 1



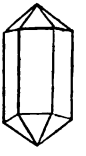
II. *Pyramidal, square prismatic*, or 2-*and*-1-*axed system*. The usual form is two pyramids, with square bases applied base to base, each of the faces forming an isosceles or scalene triangle, while, in the regular octahedron, the faces are equal-sided triangles. The angles at the base are replaced by planes in *harmotome*, and form a 4-sided square prism. The edges of the prism are replaced by planes in *calomel*, *peroxide of tin*, and form 4-sided and 8-sided prisms.

2



III. *Rhombohedral*, or *hexagonal*, 3-*and*-1-*axed system*, three axes being equal and one unequal. A common form of this is the 6-sided prism terminated by the 6-sided pyramid, as *rock crystal*.

3

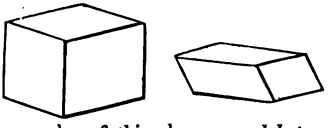


IV. *Prismatic*, or 1-*and*-1-*axed system*. The forms are principally three; first, when the faces are inclined towards all the three axes, as in the rhombic octahedron of *sulphur*; second, when the faces are inclined towards two of the axes, as in the *topaz* and *sulphate of barytes*; third, when the faces are inclined towards one axis, as in *desmin*, *chrysolite*.

4

V. *Oblique prismatic system*, of three unequal axes, 2-*and*-1-*membered system*, as in the oblique rhombic octahedron of *gypsum*. The oblique rhombic prism is a quadrangular prism, whose bases are equal rhombs, and whose lateral faces are equal oblique-angled parallelograms. The examples of this class are *felspar*, *sulphate* and *carbonate of soda*, *sulphate of iron*, *borax*. VI. Class. *Doubly-oblique prismatic system*, 1-*and*-1-*membered system*, of three axes, all unequal, cutting each other at acute angles. The

5 6



most familiar examples of this class are *sulphate of copper*, *sulphate of manganese* and *cyanite*.

The measurement of the angles in crystals is important, and is

made by means of the *goniometer* (*γωνια*, an angle, *μετρον*, a measure).

8. The comparative weight, or *specific gravity*, of a body often enables us, especially when taken in conjunction with one or more of the preceding characters, to decide upon its nature.

When we take a piece of lead in one hand, and a portion of bread in the other, we say that the former, comparing the two together, is *heavy*, and the latter *light*. The terms, therefore, heavy and light are comparative terms, used in common language to express the greater or less weights of *equal bulks* of different bodies. In order to form a precise idea of the relative weights of different substances, it is necessary, therefore, to have some fixed object of comparison. In expressing the relative weights of solid and liquid bodies, it is usual to assume pure water as a standard. A cubic inch measure, for example, of distilled water weighs, at the temperature of 60°, 252·458 grains, or nearly 252½ grains, while a cubic inch measure of mercury weighs 3425·355 grains, or nearly 3425½ grains. If we, therefore, agree to represent the weight of a cubic inch measure of water by 1, or unity, we call that number its comparative weight, or specific gravity; and to determine how many times this unity is contained in the weight of the cubic inch of mercury, or, in other words, how much heavier the mercury is than the water, we divide the weight of the cubic inch of mercury by the weight of the cubic inch of water. The result is, 3425·355 ÷ 252·458 = 13·568, which we term the peculiar weight or specific gravity of mercury. By the knowledge of the specific gravity of a body, we are often enabled to distinguish it from other substances to which it may bear a resemblance in its external appearance.* The determination of the specific gravity of a body is, therefore, generally one of the first steps in a chemical inquiry. But as bodies exist in three different states, different expedients are resorted to, bearing reference to the peculiar state of the body.

I. *Specific Gravity of a Liquid.*—It is obvious that if the body whose specific gravity we wish to determine be a liquid, the experiment is attended with no difficulty. We procure a bottle, such as is usually sold under the name of a specific-gravity bottle, which is commonly a light glass vessel, supplied with a perforated glass stopper. For liquids, a bottle capable of containing 1000 grains of water is to be preferred; but when the specific gravity of solid bodies is sought, the vessel need not exceed the half or quarter of this capacity. A cubic inch measure is a good size. The first step is to dry the bottle, by applying a sand heat to it,

7

* See Table of Specific Gravity of Minerals.—Thomson's *Outlines of Geology and Mineralogy*, Vol. ii. Appendix.

and sucking out the vapour, by means of a dry tube inserted in it. The empty bottle is then weighed. But, as what is designated in common language an empty bottle is full of air, it is obvious that in this experiment we obtain the weight of the glass, and also that of the air contained in the interior of the bottle. It is proper, therefore, to measure its capacity, and subtract the weight of the air from that of the bottle and air. A cubic inch of common air weighs 0·3114 grain, rather less than the $\frac{1}{3}$ of a grain. In a cubic inch bottle we therefore subtract this number from the weight of the empty bottle. We then fill it with distilled water at the temperature of 60°. Should the temperature happen to be below this point, as may be ascertained by immersing a small thermometer in the water of the bottle, it may be elevated by the heat of the hand; or if above this, it may be lowered by pouring cold water on the bottle, or immersing it in a small quantity of water in which crystals of common carbonate of soda are dissolving. The bottle full of water is now weighed, and its weight noted. The weight of the empty bottle, subtracted from this number, gives the weight of the water which the bottle is capable of containing. We now pour out the water and dry the bottle as before. We then fill the dry bottle with the liquid whose specific gravity we wish to determine, and weigh it. By deducting the weight of the bottle from this number, we obtain the weight of the bottle full of fluid. We have now the weight of equal bulks of water and of the fluid; and it is obvious that the same relation exists between the weight of equal bulks of the fluids as between their specific gravities. Hence we say —

The relation of the weight of the water
Is to that of the fluid,
As the specific gravity of water, or 1,
Is to that of the fluid.

Example. — Suppose the bottle, when dry, to weigh 100 grains, and when filled with water 1100 grains,

By simple subtraction we have —

Weight of bottle and water	1100 grs.
Weight of bottle empty	100
Weight of water	1000

Having removed the water from the bottle, dried it, and filled it, as before described, with mercury, we find it to weigh 13,668 grains. We have then —

Weight of bottle and mercury	13,668 grs.
Weight of bottle empty	100
Weight of mercury	13,568

Divided by 1000, the weight of the water, we have 13·568, as the specific gravity of mercury; or, in other words, mercury is rather more than 13½ times heavier than water.

Precautions in Weighing.

(1.) See that the scale-pans are clean and bright before beginning and after finishing a weighing, and that the scale-case is free from dust.

(2.) Take out the weights from their box as required, and return the superfluous ones immediately to their place.

(3.) Never allow weights or bodies to remain in the scale-pans after you have completed your weighing. But weigh quickly; return the weights to their case; see that the scale-pans are supported, are clean, and bright, and free from moisture; and then shut up the scale-case.

(4.) Never allow a chemical body to touch the pans, but let it always be placed either in glass or on glazed paper. A light glass tube is to be preferred to every thing else when it can possibly be employed.

(5.) A specific-gravity bottle should always be lifted by the neck or made to rest on a cloth, so as to avoid raising the temperature of the contained liquid above 60°. The bottle should be carefully dried with a clean cloth, and the stopper cleared of exterior moisture by means of blotting paper.

Practical Application of the Specific Gravity of a Fluid.

By a knowledge of the specific gravity of a fluid, we are enabled to determine the weight of a given bulk of the same fluid.

Example. — The weight of an imperial gallon (measuring 277·274 cubic inches) of distilled water being 70,000 grains, to determine the weight of an imperial gallon of Dunblane mineral water, whose specific gravity is 1005·475, we have only to recollect that the same relation must exist between the specific gravity of distilled water and the specific gravity of the mineral water, as between the weight of an imperial gallon of distilled water and the weight of an imperial gallon of mineral water; or, as

1000 : 1005·475 :: 70,000 : 70383.

This step being gained, we can easily, from the analysis of 1000 grains of the water, determine the amount of each constituent in an imperial gallon. 1000 grains of Dunblane water contain 4·0038 grains of common salt. To obtain the amount in the imperial gallon, we must remember that there is the same relationship between the weight of water experimented on and the

weight of its gallon, as between the common salt contained in the amount of water experimented on and the quantity in the gallon; or, as

$$1000 : 70383 :: 4{\cdot}0038 : 281{\cdot}799 =$$

the amount of common salt in an imperial gallon of Dunblane water. In like manner we proceed with the other constituents.

II. *Comparative weight, or specific gravity, of a solid in the mass.* — If we take a piece of amber of the size of a cubic inch, and place it in a glass full of rain or distilled water, we shall find that it sinks to the bottom of the vessel. It is, therefore, heavier than water. But if we dissolve common salt in the water, adding a few grains at a time, we shall find that the amber rises gradually from the bottom of the glass, and floats in the liquid. When it remains at an equal distance from the top and bottom of the liquid, it is quite clear that it can neither be said to be *heavier* nor lighter than the water. It must, therefore, be of the same weight as an equal bulk of water. This may easily be proved by ascertaining the quantity of salt required to produce the effect described, and filling a glass quite full with such a solution; place it in a basin, then introduce the amber; a quantity of fluid will run over the upper surface of the glass into the basin, which, if collected and weighed, will be found exactly equal to the weight of the amber. In this experiment if the water which runs over were measured, it would be found to occupy the same bulk as the amber introduced; and this happens in every instance of the immersion of a solid in a liquid.

Further, the bulk of water, previous to displacement, was buoyed up in its place by a pressure of the surrounding water equal to its own weight. We have a proof of this when we drop a bucket into a well and fill it with water. If we allow it to sink to the bottom, we can raise it again in the water without difficulty, because the water and the bucket are buoyed up by the surrounding particles of water; but when we attempt to raise it above the surface of the water we experience the whole weight of the bucket and water, because it has lost the support of the water, and is only buoyed up by the air. When we immerse, therefore, a solid in water, we displace a quantity of water equal in bulk to that of the solid; while the solid must be buoyed up, as already explained, by a force equal to the weight of the water displaced. Hence, by weighing a solid first in air and then in water, we obtain, by taking the difference of these weights, the weight of a bulk of water equal to that of the solid.

We find, then, the same relation existing between the difference between the weight in air and water, and the weight of the solid in air, as between the specific gravity of water and the specific gravity of the solid.

Example. — Having attached a horse's hair with a loop to one of the pans of a balance, and equipoised the scales, fix the piece of solid to be examined to the loop and weigh it. Suppose the weight 126·6 grains. Introduce the suspended solid into a tumbler of distilled water at the temperature of 60°, and weigh it. Its weight is now 94·7 grains. Deducting the latter from the former sum, the remainder gives the weight of water equal in bulk to that of the solid. This amounts to 31·9 grains. We have then the ratios by weight of equal bulks of water and solid: —

31·9 : 126·6 :: 1 : 3·968 = specific gravity

of the solid; the fourth term being obtained by dividing the sum of the second and third terms by the first.

In other words, we determine how many times the weight of an equal bulk of water is contained in an equal bulk of the solid.

Precaution. — All air bubbles must be removed from the body suspended in the water by means of a wire, and also from the hair. The temperature should be as nearly as possible 60°. A difference of 10° below 60° would diminish the specific gravity in the case cited from 3·968 to 3·92.

Practical Application. — As a cubic foot of water weighs 1000 ounces avoirdupois, by taking the specific gravity of a body and its measurement, we can determine its weight. (1.) One of the granite stones on the walls of Baalbeck measures 63 feet long, 12 feet broad, and 12 thick. What is its weight, the specific gravity of granite being 3·57? Here 63 × 12 × 12 = 9072 cubic feet. Then,

1 : 9072 :: 3500 : 31752000 oz., or 855 tons 18¾ cwt.

(2.) The weight of a marble statue being 748 lbs. avoirdupois, required the number of cubic feet which it contains, the specific gravity of marble being 2·742.

2·742 : 748 × 16 :: 1 : 4·36 feet.

III. *Specific gravity of a solid by the bottle.* — Having first weighed the specific-gravity bottle full of distilled water, and noted the weight, we weigh out a certain quantity of the solid, broken into small pieces, in a weighing tube. We then introduce the solid into the bottle, and ascertain the weight of both together. It is obvious that the solid will displace from the bottle an amount of water equal to its own bulk. We have then the following proportion: —

As the difference between the weight of the bottle full of water + the substance, and that of the bottle containing both substance and water
Is to the weight of the substance,
So is the specific gravity of water
To the specific gravity of the substance.

Example.— Weight of bottle and water - - 892·55 grs.
Weight of substance - - - 30·10
Weight of bottle full of water + substance - - - - - 922·65
Weight of bottle containing water and substance - - - - - 908·20

Difference - - 14·45

14·45 : 30·1 :: 1 : 2·071 = specific gravity of substance.

IV. *Specific gravity of a body lighter than water.* — In taking the specific gravity of cork, for example, which is proverbially lighter than water, it is necessary to sink it by means of a piece of lead, copper, iron, or some other heavy body. First weigh the heavy body and the united body separately, both in air and water, and ascertain how much each loses in the water, by subtracting their weight in water from their weight in air, and deducting the less of these remainders from the greater. Then, as

This remainder
Is to the weight of the light body in air,
So is the specific gravity of water
To the specific gravity of the body.

V. *Specific gravity of a body soluble in water.* — When the substance to be examined is soluble in water, it is necessary to employ another fluid in which it is insoluble. Alcohol, oil of turpentine, pyroxylic spirit, &c. will generally answer this purpose. We first take the specific gravity of the fluid; we then take the specific gravity of the body, by means of the fluid, and have this proportion:—

As the specific gravity of water
Is to the specific gravity of the fluid,
So is the specific gravity in that fluid
To its specific gravity in water.

Example. — The specific gravity of a body was found in the mass, in alcohol of the specific gravity ·8393, to be 1·962: we have, then, $\frac{\cdot 8393 \times 1 \cdot 962}{1} = 1 \cdot 6467$ = specific gravity in water.

VI. *Specific gravity of a gas.* — In describing the method of taking the specific gravities of solids and liquids, it has been already stated that pure water is taken as the standard of comparison or unity. But in reference to gases the standard is different. Common or atmospheric air is usually employed for this purpose. In taking the specific gravity of a gas there is much greater difficulty in obtaining very accurate results than in any of the previously described problems, in consequence of the influ-

ence of various atmospheric causes. The experiment must be made in a room where there are no draughts; in short, the air must be perfectly still, and quite equable in temperature. The vessel to be employed for weighing the gases should be blown as light as possible, but should be strong enough to bear the pressure of the atmosphere when exhausted. This may be ensured by boiling the flask in oil. The first object is to ascertain, as in the case of the specific gravity of a liquid (for we must consider air merely as a rarer fluid than water) the weight of the glass flask or vessel.

8 This is effected by screwing it on the air-pump; and having ascertained that the junctions are perfectly air-tight, we pump out the air contained in it, and weigh it in this condition. We then connect it with a vessel containing air which has been standing over water, in order to saturate it with vapour, and after waiting for a few minutes till it cools, it is also weighed. Lastly, we pump out the common air, and fill it with the gas to be examined, which also should be saturated with vapour, and weigh it. Fig. 10. represents the mode of filling the flask. We have then the proportion: —

As the difference between the flask, with and without air,
Is to the difference of the flask without air and with gas,
So is the specific gravity of air
To that of the gas.

Example. — The following is the specific gravity of Glasgow street gas: —

		Differences.
Flask without air - -	768·09 grs.	
Flask with air - -	773·80 „	5·71 grs.
Flask with gas - -	771·25 „	3·16 „

We have then the proportion —

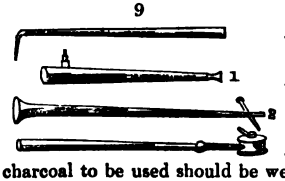
5·71 : 3·16 :: 1 : ·553 = specific gravity of the gas.

In experimenting with great delicacy, the gases should be dried before being introduced into the flask. This is effected by adjusting a tube filled with chloride of calcium between the source of the gas and the empty flask, so that the gas traversing the column of chloride is completely dried. To prevent the flask from being affected by changes of temperature, it may be suspended in a box retained at a regulated temperature. Further to equilibriate the influence of the atmospheric pressure, Regnault has adopted the method of counterpoising the flask used with another of the same capacity, instead of using merely weights.

CHAPTER II.

ON THE INTERNAL OR CHEMICAL PROPERTIES OF BODIES.

As a knowledge of the results to be obtained by the use of the blow-pipe can only be acquired by a good deal of practice, the student should provide himself with a blow-pipe (which may be had very cheap when made of tin), and practise frequently, so as to be enabled to use the subsequent tables. The cheapest form of blow-pipe is No. 1, introduced by Dr. Black. No. 2, Wollaston's blow-pipe, takes to pieces, and is, therefore, so far, convenient. In the absence of a gas or spirit-lamp, a common tallow candle will supply a flame capable of affording sufficient heat. The charcoal to be used should be well burned and free from fissures; a small cavity being made by means of the point of a knife, to retain the substance and fluxes.

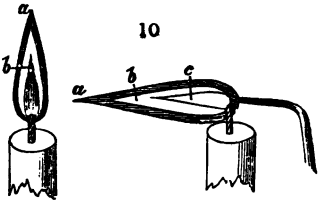


Action of the blow-pipe upon bodies. — It has been already stated that, by the influence of heat we are enabled to obtain much knowledge of the nature of many bodies. But the remarks already offered only refer to comparatively low degrees of heat, and such as can be communicated by a gas or spirit-lamp, when the substance is placed on a spatula held over it. When greater degrees of heat are to be applied it is necessary to use the blow-pipe, whether of glass or metal, bent at a right angle, and employed so to propel the flame of the lamp upon the body to be examined, as to enable the operator to observe distinctly the slightest alteration produced upon the body by the continued high temperature.

When we propel a flame by means of a blow-pipe, there are two portions of the flame which produce different effects, and therefore require particular attention. The flame of a common candle consists of an external red, and an interior blue or dark, cone.

A flame is simply a hollow cone of light, consisting of gases, which merely burn at the surface, where they are in contact with the oxygen of the atmosphere. The point *a* is obviously in contact with the air, while the point *b* is farther removed from it.

But when we blow through a flame the circumstances are altered: *b* in the first figure corresponds with *b* in the second, as in both unburned gases exist. In the second figure *a* is the oxidizing and *b* the reducing flame. To reduce an oxide to the state of metal, that is, to cause the oxygen of the oxide to combine with the flame, we place the body in the reducing flame. To oxidize a metal, so as to cause the metal to combine with oxygen, we place the substance in the oxidizing flame. In exposing a body to the action of the blow-pipe we first ascertain the effect (*per se*) by itself, simply by holding the body in the flame by means of a convenient instrument, either a thin platinum wire twisted round the substance or a pair of forceps tipped with platinum.



Action upon bodies per se. — In making this experiment a long thin fragment of the body is fixed between the points of a pair of forceps, and held in the reducing flame. This method is particularly applicable to minerals, many of which have peculiarities that assist us in deciding on their species. A certain set of minerals, amounting to about thirty-six in number, are characterised by their frothing before the blowpipe, and hence they have been termed zeolites (from ζεω, I boil). They are well typified by Thomsonite. They contain from ten to twenty per cent. of water, and when heated they part with the water, and, boiling up during the process, either fuse into a white bead or fall to powder. — (For other characters of minerals, see *Mineralogy*, vol. i.)

I. Colours produced by bodies *per se*.

Potash Salts	Violet Flame
Lithia	Purple Red
Strontian	Crimson
Lime	Red
Soda	Yellow
Barytes	Pale Green
Borates, with SO_3	Green
Iodides, with Salt of P and CuO	Green
Phosphates, with SO_3	Green
Ammonia	Dark Green
Tellurium oxide	Green
Copper	Green, except Cl. and Br. (Blue)
Zinc	Whitish Green
Bromides, with Salt of P and CuO	Blue, with Green Edges
Arsenic	Light Blue
Antimony	Greenish Blue
Selenium	Blue
Lead oxide	Blue.

II. **Odours produced.**

Arsenic	Garlic
Selenium	Horse Radish
Sulphur	Peculiar
Sulphurets	Odour of SO_2

III. *Blowpipe action on substances upon charcoal.* — The *metals*, with the exception of platinum, palladium, iridium, rhodium, and osmium, are almost all capable of being melted before the blowpipe on charcoal.

Fusible oxides. — The oxides are mostly infusible, with the following exceptions: —

Antimony, oxide	Bismuth, oxide
Vanadic acid	Lead ,,
Tellurous ,,	Copper ,,
Molybdic ,,	

Volatile metals.—The following metals sublime, leaving a powder on the charcoal: —

Arsenic	White Sublimate.	Cadmium	Yellow
Antimony		Bismuth	
Tellurium		Lead	
Zinc		Tin (trace)	White

Mercury and osmium volatilize, without producing a sublimate.

Reducible bodies.—Most metallic oxides are reduced to the metallic state on charcoal. The exceptions are, the alkalies, earths, cerium, uranium, manganese, iron, vanadium, chromium, tungsten, columbium, titanium.

IV. *Blowpipe action with carbonate of soda.* — Bodies fusing into a bead on platinum wire in oxidating flame.

Silica	Colourless glass	Manganese oxides	Green
Antimony, oxide and acids	White	Cobalt oxide	Red, and then grey
Tellurium, oxide and acid	Colourless when hot, opaque when cold	Copper oxide	Green when hot, colourless when cold
Chromium oxide,	Orange in oxidating, green in reducing	Lead oxide	Transparent when hot, yellow and opaque when cold
Molybdic acid	Milky		
Tungstic acid	Yellowish		
Titanic acid	Yellow glass when hot, white when cold		

Metals subliming on charcoal with carbonate of soda.

Arsenic	Tellurium	Lead
Antimony	Zinc	Bismuth
Selenium	Cadmium	

Metals reduced on charcoal with carbonate of soda.

Molybdenum	Cobalt	Silver
Tungsten	Copper	Gold
Iron	Tin	Platinum.
Nickel		

Bodies neither fused nor reduced. — The alkaline earths, the earths, oxides of cerium, oxide of uranium, columbic acid.

V. *Blowpipe action with borax — colour of beads.* — Experiments with borax or carbonate of soda are generally conducted on platinum wire.

Oxidizing flame.		*Reducing flame.*
Colourless,	Lime, Barytes, Strontian, Magnesia, Alumina, Glucina, Yttria, Zirconia, Thorina, Silica, Columbic acid, Cadmium, Zinc, Tin	Colourless
	Tellurium	Gray
	Antimony	Gray
	Molybdic acid	Reddish Brown
	Tungstic acid	Yellow
	Titanic acid	Yellow, hot; violet or dark blue, cold
	Silver	Gray
	Bismuth	Gray
Green	Chromium, when cold	Green
	Copper	Brown
	Cerium	Colourless
Red	Iron	Green
	Nickel	Gray
Blue	Cobalt	Blue
Violet	Manganese	Colourless
	Uranium	
Yellow	Vanadium	Green
	Lead	Gray.

VI. *Blowpipe action with salt of phosphorus — colour of beads.* — Microcosmic salt, or ammonia-phosphate of soda, when heated, parts with its ammonia, and is converted into biphosphate of soda.

Oxidizing flame.		*Reducing flame.*
Yellow	Vanadium	Green
	Uranium, while hot	Green
	———, green while cold	
	Bismuth	Gray
	Silver	Gray

Oxidising flame.		*Reducing flame.*
Blue	Cobalt	Blue
Violet	Manganese	Colourless
Red	Cerium	Colourless
	Iron	Green
	Nickel	Red
Green	Chromium, when hot yellow	Green
	Uranium, when hot yellow	Green
	Molybdic acid	Blue when hot, green cold
	Copper	Brown
Colourless	Tungstic acid	Red if iron present, blue without it
	Antimonious acid	Red with iron
	Antimony oxide	Gray
	Titanic acid	Red with iron, violet or blue without it
	Tellurium	Gray
	Lead, yellow when hot	Gray.

The alkaline earths, earths and other bodies not enumerated, give colourless or milky beads in both flames.

Testing Tables.

Mode of using the Tables.

To discover the nature of the acid, a solution of the substance to be tested is dissolved in a small portion of distilled water. A portion of the solution is poured into a test-glass, three drops of nitrate of silver are added, and the first column examined to observe if the precipitate corresponds with any of those described. Another portion is placed in a second test-glass, and three drops of a solution of chloride of barium added. If the acid be a common one, it will be found in the table. If it is of rarer occurrence we must look for it in the body of the work. For the bases we proceed in a similar manner.

The reagents required in these experiments are described in the body of the work. The principal are hydrochloric acid, sulphuric acid, nitric acid, acetic acid, caustic ammonia, caustic soda and potash, chloride of barium, nitrate of barytes, oxalate of ammonia, sulphohydric acid, sulphohydret of ammonia, bichloride of platinum, nitrate of silver, phosphate of soda, solution of sulphate of lime.

Testing Analyses.

By means of the tables we should not only be able to distinguish the presence of single bases when present, but also to discriminate between a series of bases, supposing them to be mingled together.

The following examples point out the method of working the tables: —

EXAMPLE OF TWO ACIDS IN SOLUTION.

Add to a portion of the solution 3 drops of nitrate of silver: a white, curdy precipitate falls, which does not disappear when NO_5 is added, even after boiling. It dissolves in NH_3. It is, therefore, *chlorohydric* acid, the precipitate formed being chloride of silver. Add to a second portion 3 drops of solution of BaCl; a white powder falls, insoluble in NO_5, which is $BaO\ SO_3$, indicating the presence of SO_3 in the solution. The solution then contains the two acids, HCl and SO_3.

EXAMPLE OF TWO BASES IN SOLUTION.

Add 2 drops of NH_3 slowly: a brownish precipitate falls, with a white shade. The addition of a few drops more of the NH_3 removes the white tint; a reddish brown precipitate remains undissolved. Throw the whole on a filter. To the filtered liquid add HCl till the solution renders litmus paper slightly red. When a drop of NaO is added to a portion of it, a white, flocky precipitate appears. An excess of soda redissolves the precipitate. SH, when passed through another portion, gives a white precipitate; and NH_3SH has a similar effect, not redissolved in excess. *The precipitate dissolved by NH_3 is, therefore, oxide of zinc.* The reddish brown precipitate on the filter is dissolved off by dilute HCl. On the addition of NaO to a portion of the solution, a reddish brown precipitate falls. SH drops sulphur when passed through another portion of the solution. NH_3 SH renders another portion black; while yellow prussiate of potash yields with another portion Prussian blue. *The precipitate undissolved by the NH_3 is therefore sesquioxide of iron.*

PROCESS WHEN THE PRECIPITATE IS WHITE.

Supposing the precipitate to be of an unmixed white colour, we observe from the first table that it may be one or more of twelve bodies, and besides, when we have added an excess of NH_3, that there may be a base held in solution by that reagent. The first step then is to filter the liquid; the precipitate remains on the filter, and the ammoniacal liquor passes through. We saturate the latter with a few drops of acid, and then add ammonia drop by drop, and watch carefully if any precipitation takes place before an excess is added. If a precipitate appears and is again dissolved, the substance belongs to Class III. If no precipitate appears, some of the substances included under Class II. may be present, which are therefore to be tested for by the appropriate reagents. Dilute hydrochloric acid is now to be

poured on the filter, when the precipitate will pass through in solution. Caustic soda is to be added in excess to the solution of the precipitates, and the liquid filtered. The filtered liquor is to be saturated with HCl, and NH_3 added. If a precipitate appears, it must be one or more of the following substances: —

Alumina	Lead protoxide
Glucina	Tin protoxide,

as these are the only white hydrous oxides which are soluble in caustic alkalies. To distinguish these, we find by Table III. that lead and tin are precipitated by SH, while alumina and glucina are not affected. We, therefore, dissolve the precipitate in HCl, and pass a current of SH through the solution. If a black precipitate appears, it may consist of both lead and tin. The precipitate is thrown on a filter, and washed with sulphohydret of ammonia. If tin is present it will be dissolved, and pass through the filter, while the lead will remain as a black precipitate. To detect the tin the filtered liquor is boiled with HCl till SH is driven off, and the distinguishing tests for tin employed. The sulphuret of lead on the filter is dissolved in HCl, and tested with SO_3 and chromate of potash. If alumina and glucina are present, they will remain dissolved in the liquid through which the SH has been passed. The gas is to be boiled away, and carbonate of ammonia added in excess. If alumina is present it will remain undissolved, while the glucina will be dissolved by the alkali. The liquid is therefore to be filtered, the solution which passes through neutralised by HCl, and NH_3 added. If glucina is present it will fall. The substances which may remain on the filter which are insoluble in caustic soda are the following —

Magnesia	Titaniate
Yttria	Bismuth
Cerium oxides	Mercury oxide
Lantana	Antimony oxide.
Zirconia	

The first 6 are not precipitated by SH, while the three last are precipitated by SH, as appears by Table III. By transmitting a stream of SH through the solution, therefore, these three metals will be precipitated. After filtration, by adding NH_3SH, according to Table IV., the antimony will be dissolved, and may be precipitated from its solution by boiling the liquor and passing SH through it. An orange precipitate will fall. The bismuth and mercury may be separated by evaporating to dryness, dissolving the residue in NO_5, and adding water, the trisnitrate will precipitate as a white powder, while after filtration the mercury may be precipitated as yellow hydrate with caustic soda, or as

iodide, by means of iodide of potassium, in the form of a beautiful red powder.

The precipitate on the filter is dissolved in HCl, the solution neutralised, and NH_3SH added. Magnesia, if present, will remain in solution, while the titanic acid and earths will be thrown down in the form of bulky white precipitates. After filtration the magnesia may be precipitated by phosphate of soda and carbonate of NH_3. The earths remaining on the filter are now to be distinguished. The oxides of cerium and lantanum, and zirconium and yttrium, are first separated by means of a saturated solution of sulphate of potash; a double salt is formed insoluble in the solution. The double salt of zirconia is nearly insoluble in water and acids, while those of the other two earths can be dissolved in much water. Zirconia, after ignition, is insoluble in acids, SO_3 excepted, while yttria is soluble in the same circumstances. Titanic acid is easily distinguished by its being precipitated by boiling, and when precipitated, by its insolubility in HCl.

PROCEEDING WHEN THE PRECIPITATE IS COLOURED.

By acting on the precipitate with caustic soda we separate oxide of chrome and oxide of iridium, which are both soluble in that reagent. These may be separated from each other by NH_3SH, which throws down iridium, and redissolves it, but not chrome. The remaining oxides may then be divided into those which are precipitated by SH, and those which are not acted on by that gas.

Precipitated by SH.		*Not precipitated.*
Antimony oxide	Orange.	The earths.
Mercury oxides	Black.	Uranium oxides.
Bismuth oxide	Black.	Manganese oxides.
Molybdenum oxides	Brown.	Vanadium oxides.
Lead oxide	Black.	Iron protoxide.
Osmium oxide	Yellow.	Iron peroxide (S. falls).
Tin oxide	Brown.	
Platinum oxide	Brown.	
Rhodium oxide	Brown.	
Iridium oxide	Brown.	
Palladium oxide	Black.	

The precipitate is to be washed by decantation, and then treated with an excess of NH_3SH. The following will be dissolved:—

Soluble in NH_3SH.	*Insoluble in NH_3SH.*
Antimony oxide.	Mercury oxides.
Molybdenum oxide.	Bismuth oxide.
Tin protoxide.	Lead ,,
Platinum ,,	Rhodium ,,
Iridium ,,	Palladium ,,
Osmium ,,	

These are then to be tested for by the distinguishing tests.

TESTS FOR ACIDS.

ACIDS OF COMMON OCCURRENCE.

		Nitrate of Silver. $AgONO_5$.	Chloride of Barium. BaCl.
Sulphuric,	SO_3	O.	*White* powder, insol. in NO_5. ($BaO\ SO_3$.)
Nitric,	NO_5	O.	O.
Chlorohydric, (Muriatic)	HCl	*White* curdy, insol. in NO_5. (AgCl.)	O.
Carbonic,	CO_2	*White* curdy, sol. with effervescence in NO_5. ($AgO\ CO_2$.)	*White*, soluble with effervescence in NO_5. ($BaO\ CO_2$.)
Pyrophosphoric, (Bibasic phosphoric acid)	PO_5	*White*, sol. without effervescence in NO_5. ($2\ AgO\ PO_5$.)	*White*, sol. without effervescence in NO_5. ($2\ BaO\ PO_5$.)
Oxalic,	C_2O_3	*White*, sol. in NO_5.	O. free; *White*, neut.
Antimonic,	SbO_5	*White* do.	*White*.
Iodohydric,	HI	*Whitish-yellow*, insol. in NH_3. (AgI.)	O.
Cyanohydric, (Prussic)	HCy	*White* curdy, sol. in boiling NO_5. (Ag Cy.) Smell of HCy	O.
Sulphurous,	SO_2	*White*, sol. in NO_5.	*White*, sol. in HCl.
Hyposulphurous,	SO_2S	*White*, then *black*.	O.
Hyposulphuric,	SO_2 SO_3	O.	O.
Acetic,	C_4H_3 O_3	O.	O.
Tartaric,	C_8H_4 O_{10}	*White*.	*White*.
Phosphoric, (Tribasic.)	PO_5	*Yellow*, sol. without effervescence in NO_5. ($3\ AgO\ PO_5$.)	*White*, sol. without effervescence in NO_5. ($3\ BaO\ PO_5$.)
Arsenious,	AsO_3	*Yellow* with NH_3. ($2\ AgO\ AsO_3$.)	*White*, with NH_3 in time.
Arsenic,	AsO_5	*Brown*, sol. in NO_5.	*White*, sol. in NO_5.
Chromic,	CrO_3	*Brown*, sol. in NO_5.	*Yellow*, sol. in NO_5.
Sulphohydric,	SH	*Black*, sol. in NO_5. with evol. of SH.	O.

Distinguishing Tests for Acids.

Nitric acid is distinguished by dropping in a solution of copperas and adding SO_3 if the NO_5 is combined; a dark characteristic colour is produced. With SO_3, and heat the odour of NO_5.

Oxalic acid precipitates a solution of sulphate of lime.

Antimonic and *Antimonious acids* an orange precipitate by SH.

Iodohydric acid. The precipitate with $AgO\ NO_5$, is scarcely sol. in NH_3, while most silver salts are quite soluble. Starch SO_3 and free Cl give a blue. Yellow with $PbO\ NO_5$.

Cyanohydric acid. Add a few drops of sol. of decomposing sulphate of iron, then two drops of NH_3, then HCl, till the precipitate appears like to Prussian blue.

Chromic acid becomes green by SH, yellow by $PbO\ NO_5$.

Arsenic and *Arsenious acids* give a yellow precipitate by SH.

Acetic acid. Smell of vinegar when heated with SO_3.

Phosphoric acid, when heated, gives *white* with $AgO\ NO_5$.

Sulphurous acid, with SO_3 and heat, smell of burning S.

Hyposulphurous acid, with SO_3, S falls, and SO_2 evolved.

Hyposulphuric acid, with HCl, SO_2 evolved, and SO_3 in solution

Tartaric acid. *White* with CaCl and CaO and KO.

NATURE OF THE ACTIONS IN THE PRECEDING AND FOLLOWING TABLES.

In the Acid Table the precipitates formed are combinations of the acid examined, with the base added, a new insoluble salt being formed. In the 1st Table of Bases all the precipitates produced are oxides, except those of mercury and peroxide of platinum, palladium, and gold. When NH_3 is added to calomel (Hg_2Cl) a blackish powder falls, 2 (Hg_2Cl) and NH_3 becoming Hg_2Cl, Hg_2NH_2 and NH_2HCl. When NH_3 is added to corrosive sublimate ($HgCl$) *white precipitate* falls ($HgCl\ HgNH_2$). When NH_3 is poured on chloride of platinum, the yellow ammonia chloride of platinum is formed (NH_3-Cl-$PtCl_2$). Ammonia forms with chloride of gold fulminating gold. In the 2d Table all the precipitates with soda are oxides, except with antimony, when a salt is formed. Potash forms with $PtCl_2$ a compound salt ($KCl\ PtCl_2$). In the 3d Table SH forms sulphurets, except with chromic acid, when the green oxide appears. In the 4th Table the earths fall as oxides, Al_2O_3 $3SO_3$ and $3(NH_3\ SH)$ becoming Al_2O_3 and $3(NH_3\ SO_3)$ with SH evolved, and chromium as green oxide.

Note. — *When bases are dissolved in organic acids, the effect of reagents is often interfered with, and the expected precipitate does not fall. A few drops of Chlorohydric acid* (HCl) *are then required.*

TABLE I.—TESTS FOR BASES.

CAUSTIC AMMONIA (NH_3).

FIRST CLASS.

PRECIPITATED AND NOT REDISSOLVED.

Earths.	Magnesia,	White
	Alumina,	
	Glucina,	
	Yttria,	
	Cerium oxides	
	Zirconia,	
	Antimony oxide, *Titanic acid*, with oxide in HCl.	
	Lead oxide, except organ. salts,	
	Tin protoxide,	
	Bismuth oxide,	
	Mercury oxide,	
Metals.	Mercury suboxide,	Black
	Chromium oxide,	Green
	Uranium oxide,	Brown
	——— *peroxide*,	Yellow
	Molybdenum protoxide,	Brown
	——— *peroxide*,	Yellow
	Manganese protoxide,	White then Brown
	——sesquioxide, *Osmium oxide*, *Vanadium peroxide*,	Brown
	Iron protoxide,	Green
	—— sesquioxide,	Brownish-red
	Platinum protoxide, With Cl.	Green
	—— peroxide, With Cl. *Rhodium peroxide*,	Yellow
	Iridium oxide, After boiling.	Blue

SECOND CLASS.

NOT PRECIPITATED.

Alkalies,	Ammonia.
	Potash.
	Soda
	Lithia.
Alkaline Earths,	Lime.
	Barytes.
	Strontian.
Arsenious acid.	
Arsenic acid.	

THIRD CLASS.

PRECIPITATED AND REDISSOLVED IN EXCESS.

Antimonious acid, Antimonic acid,	With HCl.	White
Tellurium oxide, With HCl.		
Zinc oxide,		
Cadmium oxide,		
Tin peroxide,		
Nickel oxide,		Green
Cobalt oxide, Copper oxide,		Blue
Silver oxide, (neut.)		Brown
Palladium protoxide, With HCl.		Reddish-white
Gold Peroxide,		Yellow

NOTE.—The substances in italics are of rare occurrence.

TABLE II. — TESTS FOR BASES.

CAUSTIC SODA OR POTASH (NaO or KO).

FIRST CLASS.

PRECIPITATED AND NOT REDISSOLVED.

Alkaline Earths.
- Lime,
- Barytes,
- Strontian,

Earths.
- Magnesia,
- *Yttria*,
- *Cerium oxides*,
- *Zirconia*.

— **White**

Metals.
- *Titanic acid, with oxide in HCl.*
- Bismuth oxide,
- *Cadmium oxide*,
- Manganese protoxide, then brown
- Iron protoxide, **Whitish-green**
- — sesquioxide, **Reddish-brown**
- *Uranium protoxide*, **Brown**
- —— *peroxide*,
- Platinum perox. with KO, **O.** with NaO.
- *Rhodium peroxide, by boiling*, — **Yellow**
- *Palladium protoxide*,
- Mercury oxide,
- —— suboxide, **Black**
- *Molybdenum protox.* — **Brown-**
- —— *deutoxide* — **ish-black**
- Nickel oxide, **Green**
- Cobalt oxide, — **Blue**
- Copper oxide, —
- *Osmium oxide*, — **Black**
- Gold oxide, —
- Au. on standing.
- Silver oxide, **Brown**

SECOND CLASS.

NOT PRECIPITATED.

Alkalies.
- Ammonia.
- *Lithia.*
- Potash.
- Soda.

Arsenious acid.
Arsenic acid.
Platinum protoxide.

THIRD CLASS.

PRECIPITATED, AND IN EXCESS DISSOLVED.

- Antimony oxide,
- Antimonious acid, — with KO
- Antimonic acid, —
- *Tellurium oxide*,
- *Columbic acid*,
- Alumina, — **White**
- *Glucina*,
- Zinc oxide,
- Tin protoxide,
- —— peroxide,
- Lead protoxide,
- *Iridium peroxide*, **Brown**
- Chromium oxide, **Green**
- *Vanadium oxide*, **Dirty-white**

TABLE III.—TESTS FOR BASES.

SULPHOHYDRIC ACID (SH).

FIRST CLASS.

PRECIPITATED.

Tellurium oxide,	**Brown**
Molybdenum oxides,	
Tin protoxide,	
Copper oxides,	
Platinum oxides,	
Rhodium oxide,	
Iridium oxide,	
Antimony oxide,	**Orange**
Antimonious acid,	
Antimonic acid,	
Arsenious acid (acid)	**Yellow**
Arsenic acid „	
Cadmium oxide, „	
Tin peroxide, „ and neut.	
Osmium oxide,	
Selenious acid, with HCl.	
Selenic acid,	
Lead oxide,	**Black**
Bismuth oxide,	
Mercury oxides,	
Silver oxide,	
Palladium oxide,	
Gold oxide,	
Osmic acid,	
Chromic acid,	**Green**
Zinc oxide (neut.),	**White**

SECOND CLASS.

NOT PRECIPITATED.

	Alkalies.
Alkaline Earths.	Lime.
	Barytes.
	Strontian.
Earths.	Magnesia.
	Alumina.
	Glucina.
	Yttria.
	Cerium oxides.
	Zirconia.
Metals.	Iron protoxide.
	—— sesquioxide, sulphur falls.
	Manganese oxides.
	Nickel oxide.
	Cobalt oxide.
	Chromium oxide.
	Vanadium oxide.
	Uranium oxide.
	Tungstic acid.
	Columbic acid.
	Titanic acid.

TABLE IV.—TESTS FOR BASES.

SULPHOHYDRET OF AMMONIA, NH_3 SH.

FIRST CLASS.

PRECIPITATED AND NOT REDISSOLVED.

Titanic acid, Alumina, *Glucina*, *Yttria*, *Cerium oxides*, *Zirconia*, Zinc oxide,	White
Uranium oxide, Iron oxides, Nickel oxide, Cobalt oxide, Copper oxide, Bismuth oxide, Lead oxide, Mercury oxide, Silver oxide, *Palladium oxide*,	Black
Tungstic acid, *Rhodium oxide*,	Brown
Cadmium oxide,	Yellow
Chromium oxide,	Green
Manganese oxides,	Flesh-red

SECOND CLASS.

NOT PRECIPITATED.

Alkalies.

Alkaline Earths.
- Magnesia.
- Lime.
- Barytes.
- Strontian.

Columbic acid.

THIRD CLASS.

PRECIPITATED, AND REDISSOLVED IN EXCESS.

Antimony oxide, Antimonious acid, Antimonic acid,	Orange
Selenic acid, Arsenious acid, Arsenic acid, *Osmium oxide*, *Molybdenum oxide*, Tin peroxide,	Yellow
Tin protoxide, Gold oxide, *Iridium oxide*, *Tellurium oxide*,	Brown
Vanadium oxide, Platinum oxides,	Brownish-black

Magnesia possesses many of the characters of *earths* and *alkaline earths* in common.

DISTINGUISHING TESTS FOR BASES.

FIRST CLASS.

PRECIPITATED BY NH_3.

Magnesia,	*White* by NH_3, ●. by NH_3SH. *White* by Phosphate of Soda and NH_3CO_2. Soluble in NH_3HCl.
Alumina,	Soluble in NaO and KO. Insoluble in alkal-carbonates. *White* by NH_3SH.
Glucina,	Soluble in NaO and KO. Soluble in carbonate of NH_3.
Yttria,	*White* by oxalic acid. Soluble in carbonate of NH_3. Insoluble in NaO.
Cerium oxides,	*White* by KO SO_3, nearly insoluble in HO. *Brownish-red* when ignited.
Zirconia,	Insoluble in HCl after ignition. Soluble in alkal-carbonates. Insoluble in NaO.
Antimony oxide,	*Orange* by SH. Chloride decomposed by HO.
Titaniate, in HCl.,	*Blue* colour produced by metallic zinc.
Lead oxide,	*Black* by NH_3SH. Soluble in NaO or KO. *White* by SO_3. *Yellow* by Chromate of KO.
Tin protoxide,	*Brown* by NH_3SH; dissolved by an excess. Precipitates Gold *Purple*.
Mercury suboxide,	*White* by HCl. *Black* by NH_3, NaO, and SH.
Mercury oxide,	*White* by NH_3. *Yellow* with KO or NaO. *Black* by SnCl. *Whitish-black* with a drop of NH_3SH. *Red* by KI.
Bismuth oxide,	Salts decomposed by HO. *Black* by NH_3SH. Distinguished from PbO by no precipitate with SO_3.
Chromium oxide,	*Green* by NH_3. Soluble in KO.
Uranium protoxide,	*Brownish-black* by NH_3. *Black* by NH_3SH. Becomes peroxide by NO_5.
——— *peroxide*,	*Yellow* by NH_3. *Brown* by NH_3SH, Insoluble in excess.
Molybdenum oxides,	*Brown*, not soluble in NH_3 and NaO. *Yellow*, soluble in NH_3SH. *Brown* phosph. of NaO.
Manganese oxide,	*White* then *Brown* by NH_3 and NaO. ●. by SH. Soluble in salammoniac. *Brown* by red prussiate. *Flesh red* by NH_3SH.

DISTINGUISHING TESTS FOR BASES.

FIRST CLASS — *continued.*

PRECIPITATED BY NH_3.

Osmium oxide, -	*Brown* by NH_3 and NaO. *Yellow* by SH. *Black* by Zn.
Iron protoxide, -	*Blue* by red prussiate of potash in acid solutions.
Iron sesquioxide, -	*Blue* by yellow prussiate of potash in acid solutions.
Gold oxide, - -	*Blue* by sulphate of iron. *Purple* by SnCl.
Platinum peroxide,	*Yellow* by KCl and NH_3HCl.
Rhodium oxide, -	*Rose* colour by HCl, and evaporation. *Black* by Zn.
Iridium oxide, - -	*Blue* by NH_3. A fine *blue* solution with KO.

SECOND CLASS.

NOT PRECIPITATED BY NH_3.

Ammonia, -	Alkalies.	Smell of NH_3 when boiled with NaO. *Yellow* by $PtCl_2$. Tinges flame *Green.*
Potash, - -	Alkalies.	*Yellow* by $PtCl_2$, and on igniting the precipitate KCl taken up by HO. Tinges flame *Violet.* Precipitated by tartaric acid.
Soda, - -	Alkalies.	O. by $PtCl_2$. *White* by antimoniate of potash. Tinges flame *Yellow.*
Lithia, - -	Alkalies.	*White* by phosphate of soda and ammonia. Tinges flame *Purple.*
Lime, - -	Alkaline Earths.	O. by sulphate of lime. *White* by oxalic acid. Tinges flame *Red.*
Barytes, - -	Alkaline Earths.	Immediate *White* precipitate by sulphate of lime. O. by oxalic acid. Tinges flame *Green,*
Strontian, -	Alkaline Earths.	No immediate *White* precipitate by sulphate of lime, but after some time. Tinges flame *Crimson.*
Arsenious Acid,		*Yellow* by SH. Precipitated on copper black by boiling with HCl. Sol. in NH_3SH; Solution precipitated *yellow* by HCl. or heat.

DISTINGUISHING TESTS FOR BASES.

THIRD CLASS.

PRECIPITATED AND REDISSOLVED BY NH_3.

Oxides.	
Tellurium, -	*White* dissolved by NH_3 and NaO. *Brown* redissolved by NH_3SH.
Zinc, - - -	*White* dissolved by NH_3 and NaO, and *White* by NH_3SH.
Cadmium - -	*White* dissolved by NH_3. *White* and not dissolved by NaO. *Yellow* by NH_3SH and SH.
Tin peroxide,	*Yellow* by NH_3SH, soluble in excess. Zn precip. Sn.
Nickel, - -	*Blueish-green* by NH_3 and dissolved. *Yellow-green* by red prussiate. *Blueish-green* by NaO, from ammoniacal solutions.
Cobalt, - -	*Blue*, and dissolved by NH_3. *Blue* undissolved by KO. *Brown* by red prussiate.
Copper, - -	*Blue*, and dissolved by NH_3. *Blue* undissolved by KO becomes *Black* on boiling. *Brown*, by yellow prussiate. Turns a knife dipped into it *Yellow*.
Silver, - -	*Brown*, and dissolved by NH_3. *White curdy* by HCl, insoluble in NO_5. *Yellow White* by KI.
Palladium, -	*Flesh Red*, dissolved by NH_3, *Yellow* by KO, *Yellowish-white* by HgCy precipitate. Sol. in HCl.

CHARACTERS OF GASES.

I. Soluble in water.
1. Chlorine and Chlorohydric acid precipitate $AgONO_5$, *White curdy*, insol. in NO_5.
2. Carbonic acid precipitates lime-water; precipitate redissolved by an acid with effervescence.
3. Cyanogen, with $AgONO_5$, *White curdy*, soluble by boiling in NO_5.
4. Ammonia. Odor. and precipitates $PtCl_2$, *yellow*.
5. Protoxide of nitrogen, rekindles a glowing splinter.
6. Sulphurous acid. Smell of burning sulphur. Precipitated by BaCl. Precip. Sol. in NO_5.
7. Sulphohydric acid, or Sulphuretted hydrogen, blackens lead salts.

II. Insoluble in water.
1. Oxygen rekindles a glowing splinter.
2. Hydrogen explodes when mixed with half its bulk of O, and fired.
3. Deutoxide of nitrogen forms orange fumes with oxygen.
4. Nitrogen extinguishes a taper without precipitating lime-water.
5. Carbonic oxide burns with a blue flame.
6. Carburetted hydrogen absorbed by $SbCl_3$.
7. Olefiant gas absorbed by chlorine.
8. Phosphuretted hydrogen takes fire in contact with air.
9. Arsenietted hydrogen burns with a blue flame, depositing metallic arsenic.

CHAPTER III.

SALT RADICALS. — SUBSTITUTIONAL BODIES, OR SIMPLE SUPPORTERS OF COMBUSTION.

As chemistry comprehends the study of all the bodies and their compounds, of which the earth is composed, it becomes important, not only to be acquainted with their names, but likewise to have them so arranged in the mind that the student may be able, when a substance is named, to refer it to its proper class. The number of simple substances which have been described amounts to 62, of which, however, several have been very imperfectly examined. These bodies may be divided into two great classes — NON-METALLIC and METALLIC. The non-metallic bodies exist in the three states, as gases, liquids, and solids. The elements may also be classed as electro-negative and electro-positive bodies, according to the influence exerted upon them by electricity. They may be also arranged according to their *isomorphous* properties, or their capacity to replace each other, as follows. 1. *Sulphur*, Selenium, and Tellurium. 2. *Chlorine*, Bromine, Iodine, and Fluorine. 3. *Phosphorus*, Arsenic, Antimony, and perhaps Nitrogen and Bismuth. 4. *Carbon*, Boron and Silicon. 5. *Potassium*, Ammonia, Sodium, Silver. 6. Barium, Strontium, Lead. 7. *Alumina*, Sesquioxides of Iron, Manganese, Chromium, Glucina, Zirconia. 8. *Magnesium*, Calcium, Protoxides of Manganese, Zinc, Copper, Iron, Nickel, Cobalt, Cadmium, Hydrogen. 9. Titanium, Tin. 10. Molybdenum, Tungsten, Columbium, Pelopium, Niobium. 11. Platinum, Iridium, Osmium. 12. Gold. For practical purposes, however, the divisions previously pointed out will be followed.

The following simple bodies constitute the first class to be considered: —

Oxygen.	Iodine.
Chlorine.	Fluorine.
Bromine.	

1. The title of these simple bodies indicates that they support combustion by uniting with the combustible substance Thus, when we burn a candle in common air, it is oxygen which combines with the tallow, and contributes to give out light and heat. 2. Again, when a substance containing oxygen, or any of the bodies comprised in this class, is exposed to the action of a galvanic battery, the above elements are attracted by the positive pole, and as positive bodies attract negative, it is obvious that this class must consist of electro-negatives. 3 These bodies,

unite with various vegetable substances, and in doing so remove hydrogen from these substances, by what is termed a principle of replacement or substitution. They are therefore intimately connected with H, the first member of the subsequent class. 4. They unite with a very large proportion of simple bodies, forming salts, with the exception of oxygen, which produces oxides.

Oxygen — (symbol O).

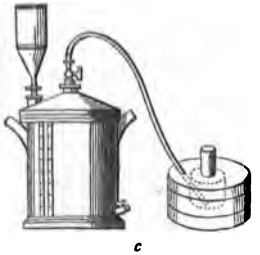
History. — Spiritus nitro-aereus (Mayow, 1672). Dephlogisticated air (Priestley, 1774). Feuerluft (Scheele, 1775). Oxygen (ὀξυς, *acid*, γινομαι, *I form*, Lavoisier, 1787). Vital air (Condorcet).

Sources. — About one-fifth of the atmosphere consists of oxygen. It exists abundantly in the earth, in union with metals forming oxides, and in all animals and vegetables.

Physical Characters. — A transparent, colourless gas, with the mechanical properties of common air, destitute of taste and smell. Specific gravity 1111 (Thomson), 1105·7 (Dumas), that of air being 1000. The weight of 100 cubic inches is 34·457 grains (Thomson), 34·289 (Dumas). Mean, 34·378 grains. Refracting power to light ·924, air being 1· (Dulong), ·861 (Biot and Arago). *Ozone* is supposed to be a variety of oxygen.

Preparation of Gases in general. — When gases are prepared in large quantities, it is usual to employ a gas-holder for their reception, and a retort for the generation of the gases.

The *gas-holder* has various forms. One of the most economical kinds consists of glazed earthenware, of the annexed shape (fig. 11.).



11

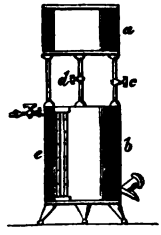
It has two apertures at the top, one of which *a* is connected with a tube which passes down to the bottom of the vessel, and is surmounted by a funnel for the introduction of water; the other aperture *b* is at the summit, and is intended for the escape of the gas. There is a third opening at the bottom *c*, by means of which the gas-holder is filled with gas. In order to fill it with water, which is the first step in preparing it for the reception of a gas, the two apertures at the top are opened, that at the bottom is closed. Water is then poured in by the funnel at the top, until the vessel is completely filled, the air escaping by the middle aperture. When filled, the two openings are closed, one by a cork, the other by a stop-cock; the lower aperture is now opened, and the beak of the retort containing the substance for generating the gas is inserted in it. The water cannot run out of the vessel, because the openings at the top are closed, and the

atmospheric pressure is therefore withheld from the surface of the water; neither can the air enter from below, because the lower aperture is placed obliquely like a bird's fountain glass, where the water exposed to the air is pressed upon by the atmosphere, upon the principle exhibited in Cooper's tube for collecting

12

gases over mercury (fig. 12.). When we fill this tube with water or mercury, retaining the stopper in it, this tube may be held vertically without any escape of fluid; and the beak of a retort or tube connected with a vessel for generating gas, being inserted in the lower opening, the gas enters and displaces the fluid. The inferior aperture of the gas-holder is constructed in a similar manner. The beak of the retort being introduced into the gas-holder as described, as soon as the gas is disengaged water begins to flow from the vessel in proportion to the amount of gas which enters; and as soon as all the water has been displaced by gas, we close the aperture, and set aside the gas-holder for use. In order to remove gas from the vessel as it is required, a bent tube is fixed to one of the apertures at the top, connected with a pneumatic trough, which is simply in this case a cylindrical vessel of earthenware, filled two-thirds with water, and having an inverted cylinder standing in it with an opening on one side for the extremity of the tube to enter, and another on its upper surface to admit of the escape of the gas from the end of the tube, and convey it into an inverted glass jar filled with water. The glass jar is thus placed by filling it in its natural position with water, covering its mouth closely with a plate of glass, and while holding it firmly, inverting it, and placing it on the shelf. The apparatus being thus arranged, the stop-cock at the top of the gas-holder is opened, the funnel is adjusted to the other aperture and opened. Water being poured

13

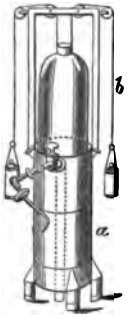


a, Water-holder.
b, Gas-holder.
c, Water tube.
d, Gas tube.
e, Gauge.

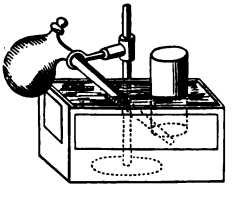
in by the funnel, the gas escapes by the bent tube and passes into the inverted glass jar in the pneumatic trough. Thus a succession of jars may be filled until the whole of the gas has been expended. A very convenient gas-holder is one made of copper, or of japanned tin or zinc, usually called Pepys' gas-holder. (fig. 13.). This apparatus consists of a cylinder (*b*) for holding the gas, and of an upper vessel (*a*) for holding the water which is intended to displace the gas. They are connected by two tubes, one (*c*) dipping to the bottom of the cylinder, and the other (*d*) entering at the top. In order to fill the gas-holder with water, the stop-cocks on the two tubes (*c d*) are opened, and water is poured into the upper vessel,

until no more air escapes by the tube which enters at the top of the cylinder. There is also a stop-cock at the side, which may be opened to facilitate the escape of the air. When full, the stop-cocks are closed. The gas-holder is filled with gas in the same way as the earthenware gas-holder. To procure the gas for use after it has been collected, an inverted jar, filled with water, is placed in the upper vessel over the opening of the short tube, and the two stop-cocks being opened, the gas rises and displaces the water in the inverted jar. Connected with the cylinder there is a glass tube or gauge, which exhibits the amount of gas in the vessel in proportion to the rise or fall of the water contained in it. Another form of gas-holder resembles that which is used in gas works (fig. 14.). It consists of a cylinder (*a*) containing water, and an inverted cap (*b*), which rises by the assistance of weights and pulleys as the gas enters.

14

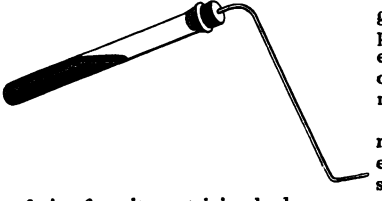


15



Gases, however, may be collected in smaller quantities, and then a gas-holder is unnecessary. The substances to supply the gas are placed in a retort (fig. 15.), the beak of which communicates with an inverted jar, placed in a pneumatic trough. Heat being generally required to facilitate the evolution of the gas, is applied cautiously by means of a spirit-lamp, or a gas-flame, covered with a wire gauze cylinder; or, when the amount of gas required is minute, a wide test tube of Bohemian glass, supplied with a perforated cork and exit tube, supported on a grasping stand, may be used (fig. 16.).

16

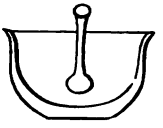


English glass does not answer for such experiments, in consequence of its liability to fusion from its containing lead.

Preparation of Oxygen.—Oxygen is obtained from various bodies, which contain it in a state of union. The substance which supplies the gas is placed in a retort or tube, and exposed to heat. The gas is evolved, and must be collected over water.

1. *From Chlorate of Potash.* —The most convenient method of obtaining oxygen is to mix equal parts of chlorate of potash, a white salt crystallizing in plates, and black oxide of manganese together in a porcelain mortar (fig. 17.); introduce the mixture finely pounded into a retort by means of a dry funnel (fig. 18.), which is placed in the tubulture of the retort, and insert the beak of the retort either in the lower aperture of a gas-holder, if the amount of gas to be obtained is considerable, or supported on a grasper-stand, and under an inverted glass jar filled with water in a pneumatic trough, if the quantity sought is smaller; or in a glass tube (fig. 16.), if the amount is to be still more minute; the mixture may also be introduced into a flask with a perforated cork and bent tube (fig. 19.). Heat being applied to the flask, the gas is disengaged. On the application of a heat of about 660°, the salt begins to decompose, and in a short time the gas is evolved in great abundance. The first bubbles of gas, being common air, should be allowed to escape, and the gas should not be collected until a glowing piece of wood inserted in the beak of the retort is relighted, the characteristic evidence of the presence of oxygen. The manganese suffers no change, but prevents the salt from fusing, and by communicating its heat to the finely divided particles of the salt renders its decomposition, which is accompanied with frequent scintillations, gradual and complete.

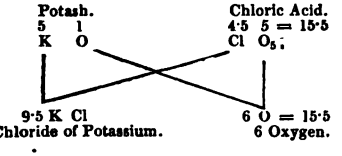
17



18

19

The mode in which the chlorate of potash is decomposed, is represented in the following scheme. It is a compound of potash or oxide of potassium (KO), and chloric acid ($Cl\ O_5$); when it is heated the whole of the oxygen passes away, while chloride of potassium remains in the retort.

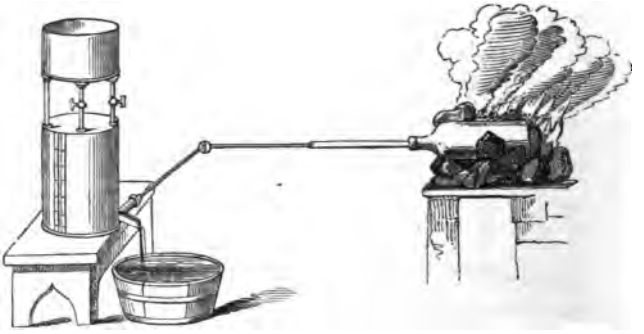


In this diagram the first line represents the substances exposed to the action of heat, and the second line the products of the reaction.

Hence we observe, that every 15½ grains of chlorate of potash yield 6 grains of oxygen gas, or 1 grain will yield ·387 grains = 1·128 cubic inches.

2. *From Black Oxide of Manganese.* — This substance is employed by itself for the preparation of large quantities of oxygen. The pounded oxide is introduced into an iron bottle, to the mouth of which is adapted an iron tube, luted with common pipe-clay and water (fig. 20.). To the extremity of this tube is

20



attached another tube, in which there is a joint, the outer end of which is introduced into a gas-holder. The iron bottle is placed in a furnace, and surrounded with red-hot coals. At a red heat the manganese parts with a third of its oxygen, which passes into the gas-holder, while the red oxide of manganese remains in the retort, represented as follows ($Mn\ O_2$ becoming $Mn\ O1\frac{1}{3}$) : —

3 Atoms Deutoxide of Manganese.

3·5	3·5	3·5	1 1 1 1 1 1	
Mn	Mn	Mn	OOOOOO	= 16·5
$14\frac{1}{2}$ $Mn_3\ O_4$ or Red Oxide.			O_2 = 16·5 2 Oxygen.	

From this diagram, we learn that $16\frac{1}{2}$ grains of perfectly pure black oxide of manganese yield 2 grains of oxygen; but as the manganese of commerce is very impure, the product is much inferior to this. The oxide often contains carbonates, the carbonic acid of which is evolved by heat, but is easily removed by allowing the gas to stand over water, when the carbonic acid is dissolved in that fluid.

3. *From Manganese and Sulphuric Acid.* — If we introduce 2 or 3 ounces of sulphuric acid into a retort (as in fig. 15.), and add to it through a funnel as much black oxide of manganese as will

form a paste, and then apply the heat of a lamp, oxygen is disengaged. It is preferable to add the acid first, and afterwards the powder, as the latter, when introduced in the dry state, adheres to the sides of the retort, and makes it liable to fracture. The action in this process is the following: —

Sulphuric acid. Black oxide of manganese.
5 3·5 1 1 = 10 5
SO_3 Mn O O

9·5 Mn O SO_3 O = 10·5.
Sulphate of manganese. 1 Oxygen.

4. Oxygen gas may also be formed from bichromate of potash, by the action of sulphuric acid and heat. KO $2CrO_3$, and $5SO_3$, becoming KO $2SO_3 + Cr_2O_3 3SO_3$ and O_3, evolved. (Balmain.)

5. Oxygen is also procurable by heating nitre (KO NO_5) in an iron bottle; likewise from red lead, red oxide of mercury, &c., by the assistance of heat.

21

Chemical Characters. — *Experiments.* — 1. Oxygen gas is proved to be a *supporter* of combustion, and not a combustible body, by bringing an inverted jar-ful of oxygen over a taper or candle, in the manner of an extinguisher (fig. 21.). The oxygen does not take fire, but the flame of the candle increases in size and brilliancy. If the same experiment is repeated with common coal gas, the gas burns at the mouth of the jar; but the flame of the candle is extinguished when immersed in the gas, and is relighted when brought in contact with the flaming gas by lifting up the jar. 2. When a splinter of wood or taper glowing, but not flaming, is introduced into oxygen gas, it bursts into flame with an audible sound, and burns with great brilliancy. This is the usual test by which the presence of oxygen is recognised (fig. 22.). 3. If finely-pounded charcoal be placed on a copper ladle attached to the extremity of a wire, (fig. 23.), and passing through a cork, be heated over a lamp till it is slightly red, and then immersed in oxygen, it glows with great vivacity, and even bursts out into flame. The product of this combustion is a colourless elastic gas, termed carbonic acid. 4. If a piece of dry phosphorus be placed in a dipper, as in the preceding experiment, heated so as just to burn, and introduced into oxygen, it burns with a brilliant illuminating effect. Or we may use (fig. 24.) a glass globe; fill it with oxygen,

22

23

and invert it over a stand upon which phosphorus is placed. Dense white fumes of phosphoric acid (PO_5) are produced, which, when shaken with water, dissolve and turn blue litmus solution red — the character of an acid. *5.* If we place some sulphur on a dipper, heat it over a lamp, and when it has fused and begins to burn, introduce it into oxygen; it burns with a fine blue flame, and gives origin to a disagreeable smelling gas, termed sulphurous acid (SO_2), which dissolves in water, and turns litmus red. 6. If a piece of fine iron wire is rolled spirally round a glass tube, or thin roller (fig. 25.), and one extremity is fixed in a cork, and the other armed with a loop of cotton wick dipped in melted sulphur; when the wick is fired, and the whole inserted in a jar of oxygen, the iron wire burns with beautiful scintillations. (Ingenhousz.) In this experiment, the bottom of the jar should be completely covered with a layer of sand, or the jar should be open at both ends; otherwise the red-hot fused drops of oxide of iron formed by the combustion will fall on the glass, and fracture it. 7. That the varieties of colour which sometimes appear in combustion, depend upon the combustible substance, and not upon the oxygen, may be observed by inserting a piece of phosphorus in a little ball of zinc filings, heating it and immersing it in oxygen; a pure white flame is the result. 8. An animal, when placed in an atmosphere of this gas, lives from four to five times longer than in an equal bulk of common air. 9. When the dark venous blood of animals is exposed to the action of this gas, it acquires a florid arterial colour. 10. 100 volumes of water absorb 4·6 of oxygen.

24

25

Oxidation.—When oxygen unites with another body, that substance is said to be *oxidated* or *oxidized*. The resulting product is an *oxide*, if it possesses the power of uniting with acids; and it is termed an acid if it is capable of combining with what are generally esteemed bases. Oxygen, like other bodies, does not unite with other bodies in any proportion, but always in definite weights. Thus, in the yellow oxide of lead (PbO), 1 grain of oxygen is united with 13 grains of the metal lead, and in the brown oxide of the same metal, 2 grains of oxygen are united with 13 of lead. Hence we say, that 1 or 100 is the combining or atomic weight of oxygen, and 13 or 1300 the combining weight of lead.

Nomenclature. — The amount of oxygen present in an oxide is indicated by the term. *Protoxide* denotes 1 atom of oxygen with 1 of base (BO); *Deutoxide*, or *Binoxide* (BO_2), 2 of oxygen, and 1 of base; *Teroxide* (BO_3), 3 of oxygen, and 1 of base, &c. Sometimes the term *per*, or thorough, is used to denote the highest degree of oxidation; *Sesqui*, one and a half. Greek numerals denote an increase in the base, as B_2O, is a *Disoxide*, or *Dinoxide*, while B_3O is a *trisoxide*. The same nomenclature is applied to the acids. All these terms were introduced into Chemistry by Dr. Thomas Thomson. These combinations are explained by the *Atomic Theory* (Dalton, 1804), by which it is supposed, 1. That the ultimate particles of all simple bodies are *atoms* incapable of further division. 2. These atoms are all spheres, and are possessed of peculiar fixed weights, which may be represented by numbers. 3. When a substance, S, unites with another, T, in more than one proportion, the relation between them is always simple. Thus, 1 S unites with 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, 3, 4, or 5, &c. of T. In the nitrogen compounds we have NO, NO_2, NO_3, NO_4, NO_5, and in iron Fe O and Fe O $1\frac{1}{2}$; also expressed by Fe_2O_3.

Theory of Volumes. — Gases unite by equal bulks or volumes, as they are termed, or multiples of these (Gay Lussac, 1808): — 1. *When two simple gases combine in equal volumes the combination takes place without condensation, or the volume of the compound gas is equal to the sum of the volumes of the simple gases;* thus, 1 vol. of nitrogen and 1 vol. of oxygen constitute 2 vols. of deutoxide of nitrogen. 2. *When* 1 *vol. of one gas unites with half a volume of another, or* 2 *with* 1, *the resulting compound occupies* 1 *or* 2 *volumes;* thus the protoxide of nitrogen consists of 1 volume or measure of nitrogen, and $\frac{1}{2}$ volume of oxygen, the resulting volume being 1 vol. of the compound gas, protoxide of nitrogen. *Deutoxide* consists of equal volumes of the two gases; nitrous acid, of 1 nitrogen, and $1\frac{1}{2}$ oxygen; hyponitric acid, of 1 nitrogen, and 2 oxygen; half a volume of oxygen being equivalent to an atom, while volumes and atoms of other gases are equal.

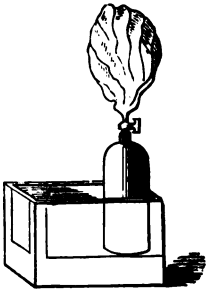
Combustion. — Oxygen, it has been stated, supports combustion, but is not itself capable of burning. In order that combustion may take place, two circumstances are necessary, the presence of a supporter, and a combustible body. When phosphorus burns in oxygen gas, phosphorus is the combustible, and oxygen the supporter of combustion, and the white fumes, termed phosphoric acid, are the product of this combination.

During this process we observe that much light is evolved, and if we apply the hands to the vessel in which the experiment is performed, we detect the extrication of heat. The cause of the heat is supposed to depend upon the circumstance that oxygen in

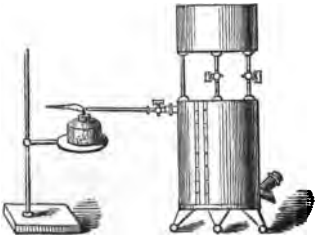
its free state contains a quantity of heat united to it, which it does not require when it combines with the combustible; hence it parts with it, and heat is appreciable. The source and cause of the evolution of heat in combustion is still involved in much obscurity. It is a subject, however, of great interest, in reference to the economical use of fuel, and deserves to be investigated. Oxygen is capable of combining with substances in a slow and comparatively silent manner. Thus, if a portion of phosphorus be dried and taken into a dark room, it becomes luminous even in cold weather; and white fumes are at the same time produced by the union of the phosphorus with the oxygen of the atmosphere. This is an example of slow combustion, which is carried on upon a large scale in nature in the decay of wood and vegetable substances, which are almost imperceptibly converted from a solid form by the union of the oxygen of the air with their carbon and hydrogen, into a colourless elastic gas (carbonic acid) and water.

Application. — Oxygen is used in the Gurney or Bude light, (the first name being derived from the inventor, and the second from his residence,) to mix with common gas in order to effect its complete combustion. For this purpose the oxygen is introduced from a gas-holder through a tube into the gas pipe before the gas enters the burner. This gas is also employed, in conjunction with hydrogen, to produce, when projected on lime, the intense white light called the signal or Drummond light (fig. 27.). We can imitate in some degree this experiment by filling a bladder with oxygen (fig. 26.), affixing a blow-pipe or capillary tube to it, and projecting a stream of the gas upon the flame of a lamp. If the combined jets be received on lime or a tobacco pipe, the light is white and intense. A more convenient arrangement is to project the oxygen from a gas-holder, upon the flame of a lamp supported on a stand (fig. 27.): A piece of watch spring held in the flame burns, giving out beautiful sparks, and zinc melts, and burns with a white flame.

26



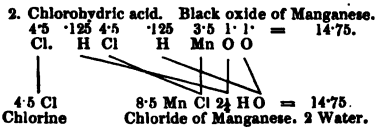
27



Chlorine.

Dephlogisticated muriatic acid (Scheele, 1774). Oxygenized muriatic acid (Berthollet, 1785). Chlorine (from χλωρος, *green*, Davy, 1810). Symbol, Cl. Sp. Grav. 2·5 or 2·47, Atomic Wt. 4·5 or 4·44, Wt. of 100 cub. inches = 77·529 grs., or 76·599. Refracting power, 2·628.

Preparation.— Chlorine may be prepared by introducing into a retort 6 parts of chlorohydric acid, and then from 1 to 2 parts of black oxide of manganese, so as to form a paste. It is best to introduce the acid first, and then the solid; because if the latter is placed in the retort before the fluid it adheres to the sides, and when heated is apt to break the glass, and a proper mixture cannot be made. The paste being formed, the heat of a spirit or gas-lamp is to be applied, when chlorine gas speedily passes over, which may be recognised by its suffocating and peculiar odour. The action is as follows: —


2. Chlorohydric acid. Black oxide of Manganese.
4·5 ·125 4·5 ·125 3·5 1· 1· = 14·75.
Cl. H Cl H Mn O O
4·5 Cl
Chlorine
8·5 Mn Cl 2½ H O = 14·75.
Chloride of Manganese. 2 Water.

One atom of chlorohydric acid loses its chlorine, which passes off in the form of gas, while the second atom of chlorine unites with the manganese; the two atoms of hydrogen of the hydrochloric acid unite with the oxygen of the oxide of manganese to form water. The gas may be received over water, and may be kept in stoppered bottles, the stoppers of which are well smeared with lard. Chlorine may also be prepared by heating in a retort equal parts of common salt, and black oxide of manganese, with double the weight of each of sulphuric acid. The formula to express the action is as follows: $NaCl\ MnO_2\ 2\ SO_3$, become $NaO\ SO_3$ and $MnO\ SO_3$ and Cl.

Characters.—Chlorine, thus prepared, is a greenish yellow gas, possessing a peculiar odour, and irritating action on the nostrils and throat, and produces symptoms resembling a common cold. It is twice and a half heavier than air; 100 measures of water at 60° absorb 200 vols. chlorine (Dalton), to 260 (Pelouze). When the solution is exposed to a cold of 36°, yellow crystals are formed, which consist of 1 chlorine and 10 atoms water. *Experiments.* — 1. Chlorine cannot be inflamed, but if a taper be immersed in it, the gas burns with a low red flame, giving out much smoke (fig. 22.). 2. Phosphorus introduced into chlorine on a dipping ladle, spontaneously catches fire, and burns with a yellowish white flame (fig. 23.). 3. Several of the metals, such as antimony, arsenic, tin, iron, zinc, mercury, or Dutch leaf, when in a fine state of division, heated, and then showered into chlorine gas, catch fire, and produce compounds of the metal, with chlorine, which

are called *chlorides*. Hence chlorine is a simple supporter of combustion. 4. When a feather moistened with oil of turpentine is introduced into chlorine, heat and light are evolved, and lamp-black is deposited. 5. When moistened blue litmus paper is introduced into the gas, the blue colour immediately disappears, or is *bleached* or *blanched*. A similar effect occurs when cloth dyed red is placed in a moist state in the gas. Green leaves of plants and flowers are also deprived of colour by chlorine. 6. When chlorine is exposed to a pressure of four atmospheres it condenses into a yellow fluid, which evaporates rapidly in the air. 7. When equal measures of chlorine and hydrogen are mixed and inflamed by means of a taper, they combine, forming hydrochloric acid (H Cl). 8. Gold or Dutch leaf placed in chlorine catches fire, forming with gold a chloride (Au Cl). 9. Mercury when heated in a ladle and introduced into chlorine, burns, forming corrosive sublimate (Hg Cl).

Applications.—Chlorine is a most important substance, in consequence of the power which it possesses of bleaching. If we allow water to stand in contact with the gas, the water becomes impregnated with it, and is then capable of destroying vegetable colours, a process which is usually called bleaching, blanching, whitening or decolorizing. This solution may be employed to remove the colour from dyed goods, and also to remove coloured spots from handkerchiefs or table cloths. A dry piece of litmus does not bleach so readily as one that is moist, the action being as follows: Cl, H O, and colour become H Cl + oxide of colour. When wine is spilt on a table-cloth, towel, or handkerchief, the stain may be completely removed by immersing it in a weak solution of chlorine. For purposes of bleaching, what is called bleaching powder, or lime impregnated with chlorine, is sold for the purpose. To prepare this substance for bleaching, it is to be digested in water, and the solution filtered. The clear liquor which passes through the filter is the bleaching liquor, which should be employed in a diluted state, otherwise it may act upon the fibre of the cloth, and weaken or destroy it. It is principally used in bleaching cotton cloth and paper. To remove the colour from woollen substances, sulphurous acid (SO_2) is employed. This solution is also used for removing noxious smells from rooms where putrid matter has gained access, and also to destroy contagious matter in places where infectious diseases prevail.

Tests. — The presence of chlorine is detected by bringing in contact with the gas a solution of nitrate of silver ($AgONO_5$) or lunar caustic. The chlorine immediately unites with the silver, forming a white curdy precipitate of chloride of silver, which is insoluble in nitric acid, but quite soluble in caustic ammonia. Every 18 grains of this precipitate, when dried, contain 4½ grains of chlorine. The best antidote for chlorine is ammonia.

Chlorine unites with *oxygen*, principally in four or five proportions.

Hypochlorous acid, or *protochlorous acid* (Cl O 5·5), is obtained by exposing the red oxide of mercury in a small flask (fig. 28.) to the action of chlorine and water. In this experiment 2 (H g O) and 2 Cl become H g Cl + H g O and Cl O. The gas is absorbed by the water, and may be obtained in a gaseous state free from water by placing the solution containing the gas in a jar over mercury, and letting into the jar small pieces of nitrate of lime. These dissolve in the water, and set free the gas. It has a yellow colour, and is decomposed by a slight heat into Cl and O. The smell resembles bleaching-powder; one vol. of water absorbs above 100 of gas. Many substances decompose it with an explosion, as charcoal, phosphorus, sulphuretted hydrogen, &c. It unites with bases forming *hypochlorites*. (Balard.)

28

Chlorous acid.—*Terchlorous acid* (Cl O_3) is a yellow gas obtained by mixing 15 parts arsenious acid, 20 chlorate of potash, pulverising, and making into a paste with water, adding 16 nitric acid, and 20 water. On applying heat the gas comes over. (Millon.) Sp. Grav. 2·646. 1 Water dissolves 5 gas.

29

Hypochloric acid.—*Quaterchlorous acid*, *Quadroxide of chlorine*, Cl O_4, At. Wt. 8·5 (Davy), prepared by mixing 50 grains melted chlorate of potash with sulphuric acid into a dry paste, and heating the mixture in a small glass retort in a water bath, the fluid of which must never rise to 212°. A yellowish green gas is evolved, soluble in water. It must therefore be received in a pneumatic trough filled with mercury. In this action 3 chloric acid of the chlorate of potash are resolved into 2 hypochloric acid, and 1 perchloric acid (3 Cl O_5=2Cl O_4 and Cl O_7). The evolution of this gas may be exhibited by a beautiful experiment. If we throw a few pieces of chlorate of potash into a test glass (fig. 29.), with some bits of phosphorus, fill up the glass with water, and then add sulphuric acid in a sucker, the chloric acid gives off hypochloric acid, and this again supplies oxygen to the phosphorus, and the phenomenon is exhibited of a light burning under water, accompanied with a series of successive explosions.

Chloric acid—*Quintochloric acid* (Cl O_5 9·5).—This acid is produced when a stream of chlorine is passed through a solution of caustic potash in water. At first there is formed a mixture of chloride of potassium and hypochlorite of potash, the latter of which ultimately becomes chlorate of potash (K O Cl O_5). Chlorate of potash is a white salt, crystallizing in plates. It readily parts with its oxygen when it is struck in contact with combustible substances. 1. Thus, if we pound a portion of it, and wrap it up in paper with a piece of phosphorus, and strike it on an anvil, it detonates with great force. 2. A similar explosion can be produced by striking it in contact with sulphur. 3. When it is mixed with pounded sugar, and sulphuric acid is poured on it, a fine combustion takes place. It is the principal constituent of lucifer matches. A match was formerly used which was made by melting sugar and chlorate of potash together, and while the mixture was soft dipping a wooden match into it. When this was introduced into sulphuric acid, a slight explosion took place, and the wood was ignited.

Chloric acid may be isolated by decomposing the potash salt with fluosilicic acid, filtering the solution, and evaporating it

under a temperature of 86°. It is a whitish liquid. Chlorate of potash is of great service in the analysis of organic compounds, in consequence of the facility with which it parts with its oxygen.

Test: gives out a greenish yellow gas by SO_3, deflagration with C and S.

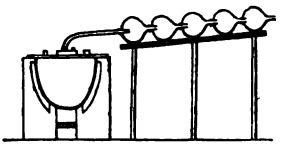
Perchloric acid, Septachloric acid ($Cl\ O_7$).—This acid is formed in union with potash when the chlorate has been heated, and has begun to give off oxygen in abundance. The acid may be isolated by means of a fluosilicic acid. The concentrated fluid has a spec. grav. of 1·65, is destitute of smell, has an acid taste, and the boiling point at 400°. When distilled with 4 to 5 times its weight of sulphuric acid, a portion of it is obtained in 4-sided white prisms which smoke in the air. *Chlorochloric acid* is $Cl_3\ O_{13}$, and *Chloroperchloric* is $Cl_3\ O_{17}$.

IODINE.

Symbol. At. Wt. I 15·75. — (From *ιωδης, violet.*) — Discovered in kelp, in 1811, by M. Courtois. It exists in many sea-weeds in combination with sodium. When these sea-weeds are collected, dried and burned, a quantity of ash remains, which is termed kelp. It is from this ash that iodine is procured.

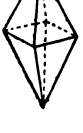
Preparation. — Kelp procured by the combustion of sea-weed derived from the deep sea is richest in iodine. Kelp when digested in water leaves earthy salts undissolved. The liquor is drawn off and evaporated in order to deposit carbonate of soda, sulphates of soda and potash, and chlorides of sodium and potassium. The residual liquor now contains the iodide of sodium, with certain chlorides, carbonates, and sulphurets. Sulphuric acid is added to it in slight excess, and allowed to remain for 36 hours. Black oxide of manganese is then added, and the mixture introduced into a still which is connected with a number of glass receivers fitting into each other (fig. 30.). The still of iron, lined with lead, is placed in brick work, and is heated by a fire beneath, which requires to be well regulated, so as not to exceed 212°; as at 244° chloride of iodine, and no free iodine, passes over. The object of the manganese is to supply oxygen to the sodium which is converted into soda, and then unites with the sulphuric acid.

30



Properties.—Iodine, when pure, has a grayish black colour, with a metallic lustre. It generally occurs in scales, but its proper crystal is a rhombic octahedron. Sp. grav. 4·948. Melting point, 224½°. Vapour point, 347°; colour of vapour violet. Non-conductor of electricity. Smell of the vapour like chlorine. Taste acrid, hot; poisonous. Stains the skin yellow. Soluble in 7000 parts of water.

31



Test. — The most delicate test for iodine is starch. Dissolve the starch in boiling water, and if the iodine is supposed to be in a free state, add a portion of the starch solution to that of the iodine. If the latter is present, a

fine blue colour is produced. But if the iodine is in union with a base as in kelp, then it is necessary to add an acid, and also a solution of free chlorine, or to hold a bottle of chlorine over the solution after the addition of a mineral acid. The chlorine unites with the hydrogen of the water and sets free the oxygen, which oxidizes the base with which the iodine is in combination, and enables the mineral acid to unite with it, while the iodine is set free, and then combines with starch and exhibits its characteristic blue colour. *Estimation.*—Iodine is best estimated by a solution of chloride of palladium; Pd I falls when the two solutions are mixed, which may be filtered and weighed upon a weighed filter. Every 22·5 grs. of iodide of palladium contain 15·75 of iodine. The only objection to this process is the presence of K S, when the sulphur should previously be oxidized.

Uses. — Iodine is used in medicine when dissolved in alcohol. It is also used extensively for the same purpose in the form of iodide of potassium, and it is said now to be used on the Continent in calico printing. When an overdose of it has been taken, the best antidote is iron filings.

Iodic acid ($I O_5$ 20·75). — If we boil 80 parts of iodine, 75 chlorate of potash, 1 nitric acid, and 400 water in a flask, for some time, and then add nitrate of barytes, a precipitate of iodate of barytes falls, from which the iodic acid may be separated by sulphuric acid. The iodic acid by evaporation is obtained in the form of a white crystalline powder, or in 6-sided crystalline plates, which appear to be segments of an octahedron; without smell; sour astringent taste; heavier than sulphuric acid, very soluble in water; with a solution of morphia gives a reddish brown colour. The iodates closely resemble the chlorates. *Test.* — Oxygen is evolved when the acid is heated, and I dropped. $S O_2$ evolves iodine detected by starch. There are various other oxygen acids of iodine of no peculiar interest, except from their analogy to the chlorine compounds, as hypoiodic acid (IO_4), periodic acid (IO_7), the former obtained by heating iodic acid with SO_3 in a crucible, and the latter by heating iodate of soda with hypochlorite of soda.

Bromine (*Βρωμος, fetid smell*).

Symbol, Br. at. wt. 9·75. sp. grav. 2·96. Discovered by Balard in 1826, in the mother liquor of the brine springs of Montpellier. It is found in sea water and in many mineral springs.

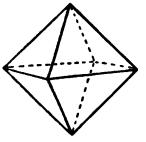
Preparation.— The water supposed to contain bromine is concentrated. A current of chlorine is passed through it; the chlorine unites with the magnesium, with which the bromine is naturally united, and sets free the bromine. A quantity of ether is now added, with which the liquid is to be agitated in a closed flask. The ether dissolves the bromine, and carries it to the top

of the liquid, where it swims as a coloured solution. By evaporation the ether is removed, or the bromine may be further purified by uniting it with caustic potash, and decomposing it by distilling with sulphuric acid, and black oxide of manganese.

Properties. — Brownish red liquid, smell highly disagreeable and peculiar. Sharp and strong taste, poisonous, sp. grav. 2·96. Freezing point — 4. Non-conductor of electricity. Destroys the skin. Volatilizes in the air. It unites with water, forming regular octahedrons (fig. 32.), consisting of Br. 10 H O. Boils at 145½. Density of vapour 5·39.

Bromine is used in the Daguerreotype process to increase the sensibility of the metallic plate, and to perfect the image instantaneously. It is used also in medicine but without much advantage. *Bromic acid* (Br. O_5 14·75) is formed by agitating bromine with caustic potash. The bromate of potash is a crystalline powder resembling chlorate of potash. The acid may be isolated by forming bromate of barytes, and decomposing it with SO_3.

32



Test. — Red gas by SO_3. White precipitate with silver salts.

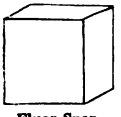
Estimation. — Bromine is estimated in a water after the separation of iodine by palladium, by precipitating the excess of palladium by SH filtering and then throwing down the bromine by an ammoniacal solution of chloride of silver.

Fluorine.

Fl 2·25. Fluorine exists in fluor spar, or Derbyshire spar, a mineral which is found in the lead mines in the form of cubes, and of a great variety of colours.

Fluor spar is considered to be a compound of calcium and fluorine (Ca Fl), a body which has not yet been isolated. Knox and Louyet state that they separated it by means of chlorine from certain fluorides, and received the fluorine in fluor spar vessels. When pure, it is said to be colourless, with a peculiar smell, decomposing water, attacking glass feebly, acting upon most metals, except gold and platinum; it does not bleach, and is more nearly allied to sulphur according to Louyet, than to oxygen.

33



Fluor Spar.

CHAPTER IV.

ACID RADICALS.

THE acid radicals or bases are divisible into two classes, *Non-metallic* and *Metallic*.

Non-metallic.		*Metallic.*
Hydrogen	gases.	Tellurium.
Nitrogen		Arsenic.
Carbon	solids.	Antimony.
Boron		Chromium.
Silicon		Vanadium.
Phosphorus		Uranium.
Sulphur		Molybdenum.
Selenium		Tungsten.
		Titanium.
		Columbium.
		Niobium.
		Pelopium.

All the inorganic acids are connected with this group, with the exception of those of manganese, iron, and osmium; but several of the latter have but slight claims to the characters of acids in consequence of their weak affinities for bases.

HYDROGEN.

History (Mayow, 1674). Inflammable air (Boyle, Hales, and Cavendish, before 1766). Phlogiston. Hydrogen, from ὕδωρ, *water*, and γενομαι, *I produce* (Lavoisier, 1787).

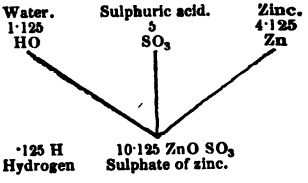
Source. — Water. Vegetable and animal substances.

Physical properties.—A transparent, colourless, elastic gas, possessing the mechanical properties of common air, without taste or smell when pure. Spec. grav. 0·0694 (Thomson), or 16 times lighter than oxygen. The weight of 100 cubic inches is 2·153 grains, or about 14½ times lighter than air. Refracting power ·47, that of air being 1 (Dulong).

Preparation.—The source of hydrogen, in whatever manner it may be prepared, is water, which is composed, as Watt suggested,

from Warltire and Priestley's experiments (1781), and as Cavendish demonstrated (1781), of oxygen and hydrogen.

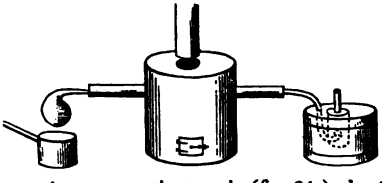
1. *By zinc and sulphuric acid.*— This is the most convenient method of preparing the gas. If we introduce 2 parts of zinc, 3 parts of sulphuric acid, and 16 of water into a retort or flask (figs. 15. and 19.), supplied with a bent tube, heat is produced by the union of sulphuric acid with water, and a copious evolution of hydrogen gas takes place. The action in this case is as represented in the diagram.

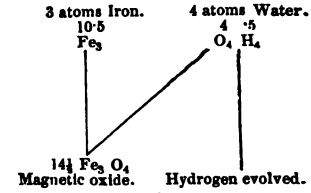


Iron or other metals may be substituted for the zinc.

2. *By passing steam over red-hot iron.*— An iron, or porcelain tube or gun-barrel, partially filled with iron-filings is to be passed through a furnace, and surrounded with red-hot coals; to one extremity is attached, by a cork, a retort containing water, and to the other also, by means of a cork, a bent tube dipping under water in a pneumatic trough, (fig. 34.); heat being applied to the water by means of a chauffer, the steam traverses the red-hot tube containing the iron-filings, the oxygen is absorbed by the iron-filings, an oxide of iron being formed ($Fe_2 O_3 + FeO$ or $Fe_3 O_4$), while the hydrogen passes by the bent tube and may be collected. This experiment is explained by the diagram.

34

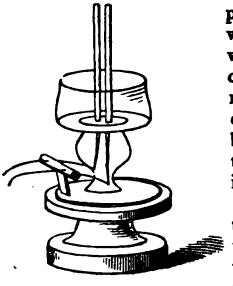




This process affords a plentiful supply of hydrogen at a cheap rate. It is necessary in this experiment to ensure the tightness of the apparatus, otherwise, if common air enter, its oxygen will unite with the hydrogen, and cause a violent explosion. Hydrogen is thus obtained by a process of *oxidation*. If the process were reversed, and the hydrogen passed over the hot oxide of iron, water would be formed by a process of deoxidation.

3. Hydrogen may be obtained from the decomposition of

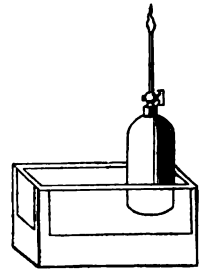
35



water by the galvanic battery (fig. 35.). An apparatus is usually sold for this purpose, consisting of a glass vessel, in which are deposited two inverted tubes, which are filled with a weak solution of common salt in water, and which are connected with two platinum wires that communicate with the two poles of a battery. Oxygen passes to the positive pole, and twice as much hydrogen is disengaged at the negative pole. Hydrogen is also extricated when potassium or sodium are brought in contact with water; the oxygen uniting with the metal, and forming a soluble oxide, termed caustic potash or soda.

Chemical characters. — Hydrogen, when perfectly pure, should have no smell; but when prepared from zinc or iron it possesses a peculiar odour due to the impurities present in these substances. Arsenic, carbon, or bituminous matter and tin, are generally present in minute quantities in zinc; and it is also suspected that when made by means of sulphuric acid and zinc, a portion of the metal is carried over in a gaseous state in union with the hydrogen. To purify it from these substances, and principally from carbonic acid and bituminous oils which are carried over, it has been recommended to pass it through alcohol (Prout), or caustic potash, and also to wash it with a solution of corrosive sublimate. *Experiments.* 1. To show that hydrogen is a *combustible* substance, and not a supporter of combustion, we fill a jar with the gas, and plunge a lighted taper into it, which is fixed to a cork accurately adapted to the mouth of the jar. When the taper is immersed in the gas, and the cork fixed, the combustion terminates. 2. If we introduce the gas into a jar supplied with a narrow tube or gas burner and stop-cock, we can burn the gas by turning the cock, igniting, and gently pressing down the jar in the water trough, and, if the flame is introduced into a dry flask, water will be deposited (fig. 36.). 3. An open jar filled with it may be ignited. In all these cases we observe that the gas burns with a pale yellow flame. 4. To exhibit its *lightness* we fill a bladder, which is supplied with a stop-cock, with common air. We adjust a common tobacco pipe to it, and blow soap bubbles by

36



37

means of a solution of soap, and gentle pressure on the bladder (fig. 37.). These bubbles not being lighter than the air speedily fall to the ground. If hydrogen be now substituted for the common air in the bladder, it will be found that the soap bubbles blown with it will ascend in the atmosphere in consequence of their lightness, and if a light be brought in contact with them they will explode. It was this property of hydrogen that led to aerostation, or the contrivance of raising balloons in the air. Dr. Black seems to have been the first individual who suggested the employment of it for this purpose. Previous to this observation fire balloons were alone used. Dr. Charles caused the first hydrogen balloon to ascend from Paris on the 27th of August, 1783. Common street gas is now employed for this purpose, as it is only about half as heavy as common air. Balloons are frequently formed of taffety, and covered with a linseed oil varnish, glue, and oil of turpentine; varnishes of copal and caoutchouc have also been used. To imitate these, small balloons are sold, which are formed of the allantois of the calf, are exceedingly light, but are very frequently not air tight. *5.* When a small flask is supplied with a perforated cork and tube terminating in a capillary opening, and hydrogen is disengaged within it from zinc and sulphuric acid, the gas escapes by the capillary tube, and can be ignited. If a long wide tube be carefully introduced, so as to surround the lighted gas, *musical* notes will be produced, varying in depth according to the length of the tubes; a variety of tubes will produce different notes. This phenomenon is produced by a series of small explosions, which follow each other so rapidly that they produce a continuous sound (Higgins, 1777). A similar effect takes place when carbonic oxide is burned. If a common medicine phial be filled with ¾ hydrogen, and ¼ common air, inverted and ignited, an identical sound is perceptible. 6. The *heating* power of hydrogen may be exhibited by taking a flask supplied with a rectangular tube, and placing under its extreme end which should be drawn out to a fine capillary point,— a piece of spongy platinum on a stand (fig. 39.). By evolving hydrogen in the flask, and causing it to project upon the platinum, so much heat is evolved as to make the metal red-hot, and to inflame the hydrogen, thus rendering this simple apparatus capable of producing an instantaneous light. Various modifications of this principle have been devised, as in Garden's lamp, consisting of two globular glass vessels, and a tube and stop-cock for the issue of the gas connected with the inferior vessel (fig. 38.). The lower vessel being nearly filled with water and dilute sulphuric acid, the upper one is inserted in it

empty, having a piece of zinc attached to the lower end of the tube. The hydrogen begins immediately to be disengaged, and, pressing

38 39 40

on the surface of the fluid, forces it up the tube into the upper vessel, when the zinc being freed from the sulphuric acid, the action ceases. The lamp is now ready for action. The stop-cock is turned, and the hydrogen, in consequence of the pressure of the column of water, is forced along the tube, and striking upon the spongy platinum placed in the little holder, causes it to become red-hot, as in the previous experiment. Fig. 40., a German lamp.

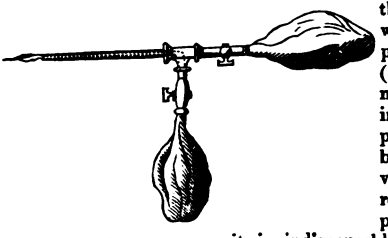
The explanation which has been given of the cause of this great evolution of heat is as follows: hammered platinum has a specific gravity of about 22, water being 1, while that of spongy platinum is only 16. Hence it appears that in every cubic inch of spongy platinum $\frac{1}{4}$ of a cubic inch is not occupied by metal, but is distributed through the powder in the form of space or a kind of capillary tubes. Now it has been ascertained that 1 cubic inch of spongy platinum absorbs 253 cubic inches of oxygen, which must therefore be compressed into the space of a quarter of a cubic inch, which is about a thousand times smaller bulk than the gas occupies at the usual temperature and pressure of the atmosphere. This condensation must, therefore, bring the gas nearly to the condition of a fluid, and enable hydrogen to enter into closer contact and unite with it. The change of the two gases in uniting to form water — from a rarer to a denser state — causes the evolution of all the heat required to keep them in the condition of gases; the platinum therefore becomes red-hot. It has been found, however, that it is not necessary for the platinum to be in a finely divided state; for if a clean plate of platinum be introduced into a mixture of two volumes of hydrogen and one of oxygen, union takes place and water is formed, — the two gases being condensed it is supposed on the surface of the platinum either by an electrical or contact action (Faraday), to which the term catalytic has been unnecessarily applied.

7. The *heating* and *illuminating* power of hydrogen, when con-

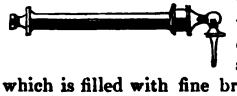
joined with oxygen, is exhibited in the oxyhydrogen blow-pipe. The simplest mode of exhibiting the effect of this intense heat, is to generate the hydrogen in a flask supplied with an ascending tube terminated with a capillary opening (fig. 41.). The hydrogen being freed is brought in contact with a jet of oxygen from a gas-holder (Mitscherlich). Another economical method is to have the oxygen and hydrogen, or common gas instead of hydrogen, in separate bladders, supplied each with a stop-cock. A common tube receives the two gases, which become intimately mixed, and issue at the nozle of the tube, which may be tipped with platinum. (Daniel). The gases may also be mixed in the proper proportion in one bladder; and to prevent the flame from retreating and exploding the mixture, it is indispensable to have what is termed "Hemming's Safety Jet," attached to the bladder (fig. 43.). This consists of a tube half a foot long, and less than an inch in diameter, which is filled with fine brass wire inserted longitudinally so as to form a series of fine tubes. The cooling effect of the metallic wires is so considerable, that if the flame were to attempt to retreat from the nozle of the tube when it is set on fire, it would be instantly extinguished. The use of this blow-pipe for chemical purposes appears to have originated at the same time (1801) with Dr. Thomson and Dr. Hare. The apparatus of Dr. Thomson is very convenient for class-room experiments (fig. 44.). It consists of two vessels of tin japanned, one for hydrogen, double the size of that intended to hold the oxygen. These are filled with gases, as in the common gas-holder. Connected with these gas-holders are two tubes which terminate above in a large reservoir to retain water, which, by means of stop-cocks, is allowed to pass down into the gas-holders to press out the gases when they are required. The two gases, when they are are to be used, escape

41

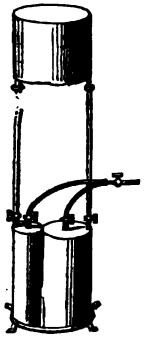
42



43



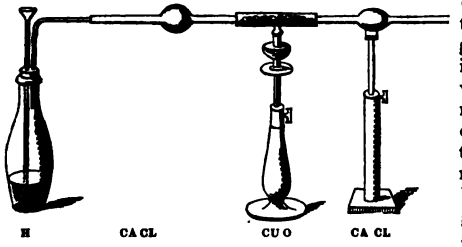
44



by two tubes into a common nozle tipped with platinum, at the point of which they are ignited. The gases being in separate vessels, there is no risk of explosion, except from a leakage in the hydrogen vessel, which would admit common air. The ignited hydrogen flame might then rush back into the mixture and explode it. Care should therefore be taken to have it perfectly air tight, and, to prevent all risk, the two tubes should be connected by Hemming's safety jet. All the illuminating and heating powers of the oxyhydrogen blow-pipe may be exhibited without much diminution of effect, by substituting common coal gas for the hydrogen. The two gases may then be kept in two separate gas-holders, or mixed in the same bladder supplied with a Hemming's jet, as already described.

Applications. — Hydrogen was formerly employed to fill balloons; but its use has been superseded by that of coal gas. It is also used as described in the oxyhydrogen blow-pipe. One of its most important uses in chemistry is to remove oxygen from bodies which contain that gas, in a solid form, by causing it to pass over these substances at a red heat. The hydrogen unites with the oxygen, and forms water, which can be taken up by a tube containing chloride of calcium (Ca Cl), a substance which has a great affinity for water. The apparatus (fig. 45.) for this purpose, consists of a flask for disengaging the hydrogen, which is supplied with a funnel tube, in order that the sulphuric acid may be added gradually—and thus a constant current of hydrogen is kept up. The oxide of copper (Cu O) may be reduced in this way, and black oxide of manganese (Mn OO) loses an atom of oxygen, being changed into the green protoxide (Mn O). In mixture with common air it has been recommended to employ hydrogen for medical purposes, the effects being to diminish the pulse, and induce sleep. Delicate colours, which alter in the oxygen of the air, may also be dyed in

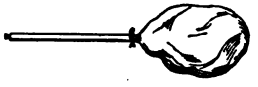
45



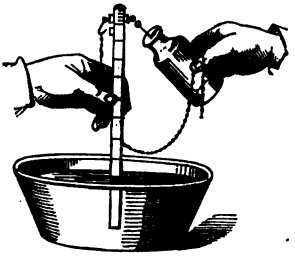
a vessel filled with hydrogen or coal gas. Water dissolves 1½ per cent.

Protoxide of Hydrogen; Water HO; atomic weight 1·125; specific gravity 1·.—1. When two measures or volumes of hydrogen gas are mixed in a dry vessel with one measure of oxygen gas, no change occurs; but if a lighted taper be brought to the mouth of the bottle in which they are contained, an explosion is produced, and the inside of the previously dry bottle is lined with a deposit of dew or water (Priestley). 2. That water is produced during the combustion of hydrogen is also demonstrated in the apparatus (fig. 36.). If the point of the tube with the burning hydrogen be inserted in an inverted dry flask or receiver, a copious deposit of water takes place in the interior of the dry flask. 3. Oxygen and hydrogen may be made to unite with a very audible report by mixing the gases in a bladder in the proper proportion (as in fig. 26.), or by bringing the bladder to the side exit pipe of a gas-holder. The bladder should have tied to its mouth a tin tube, which should be shut by means of a cork when the gases are introduced into it (fig. 46.). On withdrawing the cork, and bringing the open end of the tube to a candle, a violent explosion occurs, and the bladder is blown to pieces. 4. Common air may be substituted for oxygen in such explosions. The proper proportions are 2½ measures of common air, and 1 of hydrogen. The experiment already detailed, by which water is decomposed by the galvanic battery into 2 volumes or measures of hydrogen and 1 of oxygen, is reversed in all these explosive compounds, and the union may be effected either by means of a taper or an electric spark (fig. 47.).

46



47



The mixed gases, 2 hydrogen and 1 oxygen, are introduced into a strong graduated tube or Volta's *eudiometer*, over water as delineated, and a charged Leyden-jar discharged through the mixture. The diminution of bulk measures the amount of gases converted into water. The decomposition of water into its elements is an example of *analysis*, while the production of water by the union of the two gases is an illustration of *synthesis*.

Characters.—Water in a pure state is colourless, transparent, and

destitute of taste and smell. Its specific gravity is taken as the standard of comparison for liquids and solids, being reckoned 1. at the temperature of 60°. Its freezing point is 32°, its boiling point 212°. A cubic inch of water at 62°, barometer 30 inches, weighs 252·458 grains, or at 60° very nearly 252½ grs. The imperial gallon of distilled water, measuring 277·274 cubic inches, weighs 10lbs. or 70,000 grs. Water attains its greatest density at 39½°. When its temperature falls to 32° it freezes; an irregular prism is formed, from which others shoot out on both sides at angles of 60° and 120°. The specific gravity of ice is ·920. Water, as found in nature, always contains dissolved in it a quantity of common air, which seems mechanically lodged between its particles, because when the water is frozen or heated the air is expelled. A similar effect is also produced when soluble salts or sugar, &c. are dissolved in aerated water. But the composition of the air dissolved in water is different from that of atmospheric air, as in rivers it contains more oxygen, while on elevated mountains the amount of oxygen decreases to such an extent as to render high mountain lakes uninhabitable by fish, which require to extract oxygen from the air in water for the purposes of breathing; but this is doubtful.

Hydrates. — When water unites with a body it is termed a *hydrate*, and the state of combination is called *hydration*. Thus, if we pour water upon burned or caustic lime (CaO), the latter becomes hot, emits steam, and becomes heavier in proportion to the amount of water with which it unites. The lime thus slaked (CaO, HO) is a *hydrate*, and the lime is said to be hydrated. If it be heated to redness in the fire it loses the water, and is then said to be *anhydrous*. Water seems to act both in place of acids and bases. Thus lime, when kept away from moisture, never absorbs carbonic acid, but hydrous, or slaked lime readily takes up carbonic acid from the air, and is reconverted into chalk or limestone; while the water disappears (CaO, HO become CaO, CO_2), and in this case seems to have occupied the position of an acid. In sulphuric acid, on the other hand, it obviously acts as a base (HO SO_3); for if we bring it in contact with caustic potash (KO), the water is removed, and the potash takes its place (KO SO_3), sulphate of potash being produced, which contains no water. These present us with examples of substitution or replacement, and we thus see that chemical changes may be resolved, in a great measure, into illustrations of replacement.

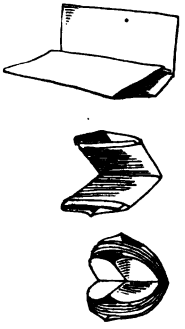
Water exists in nature in different states of purity. *Rain water* is the purest form in which it occurs; as in this state it only contains traces of carbonate of ammonia, and during thunder storms minute quantities of nitric acid. The presence of carbonate of ammonia, if it exists to any extent, may be detected by

adding to it a solution of sugar of lead (acetate of lead). If a white precipitate falls, soluble in nitric acid, the presence of carbonate of ammonia may be inferred. *River water* is the next in purity. It generally contains about 5 to 10 grains of salts in the gallon. These consist of common salt (Na Cl), sulphate of lime or gypsum (Ca O SO_3), chloride of calcium (Ca Cl), and carbonate of lime, organic matter, and earthy matter diffused through the water in such a fine state of division, that it cannot be removed by filtration. To detect the presence of most of these substances we require very few tests. Testing is best performed by means of a test glass (fig. 48.). Into this we pour a small portion of the water to be tested, and then add to it a drop or two of the test, and stir the liquid with a glass rod. If we add a solution of nitrate of silver, and obtain a white curdy precipitate, insoluble in nitric acid (Ag Cl), we infer the presence of chlorine, and therefore of common salt in the water. If a white precipitate falls on the addition of a solution of chloride of barium, insoluble in nitric acid (Ba O, SO_3), we infer that sulphuric acid is present in the water. Carbonic acid is detected by adding lime water, when a white precipitate of carbonate of lime or chalk falls, soluble in any acid with effervescence. If a solution of oxalate of ammonia throws down a white precipitate, we conclude that lime exists in the water.

48

It is impossible to purify water from any of these soluble substances; but substances mechanically diffused through water, as mud or vegetable matter, may be removed by filtration. The most easily constructed filters are made of paper or calico. Paper filters are formed by folding the paper as in fig. 49. Six filters may be cut from one foolscap sheet of paper, as in the figures. The filter (fig. 50.) is then placed in a funnel (fig. 52.), and the liquid is poured upon the side of the filter cautiously, or the water may be poured along a glass rod, which can be effected without spilling a drop of the liquid, or allowing any of it to run over the exterior of the glass. In this case the test glass is held in the right hand, and the rod in the left (fig. 51.). Filtration on a larger scale may be performed by causing the water to drain through a sponge, or a bed of sand; as for manufacturing and other purposes in large towns.

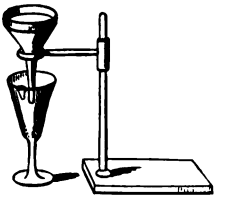
49



50

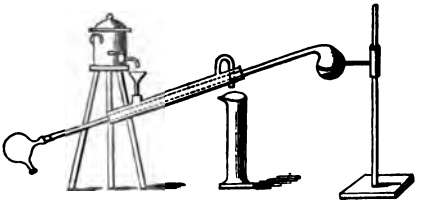
51

52

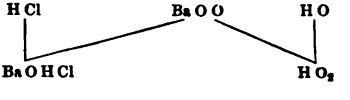


For delicate chemical purposes it is necessary to remove all the saline matter from water. This is effected by distillation, which may be conducted on the small scale by means of a glass retort and condensing tube, as in fig. 53. The condensing tube, into which the retort enters, consists of an exterior tin tube, and a glass tube which passes through the former. Water is allowed to enter at the lower end of the tin tube, and thus to surround the glass tube; when heated it rises to the upper part of the tube which is inclined for the purpose. A continual current of water is thus flowing from the supply vessel, and passing out when heated at the upper end of the condensing tube. On a larger scale a copper still and condensing worm are used. But in towns, or where steam is used, a plentiful supply of distilled water can always be procured by condensing the waste steam. *Well water* is the most impure water, as it contains a much larger quantity of carbonate and sulphate of lime than river or rain water, and in towns nitrate of lime.

53



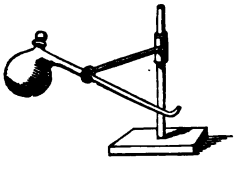
Deutoxide of Hydrogen. Peroxide of Hydrogen $H O_2$, at. wt. 2·125. — This liquid is prepared by passing a current of oxygen gas from a gas-holder, or from heated chlorate of potash over pure barytes (Ba O), in a red-hot tube; the barytes takes up an additional atom of oxygen, and becomes $Ba O_2$. This peroxide or deutoxide of barium is then introduced into water, and a little hydrochloric acid is added. The following action takes place: —

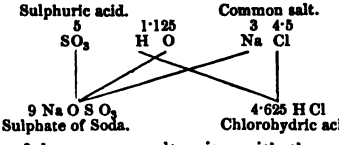


The hydrochloric acid unites with the protoxide of barium, while the second atom of oxygen passes over to the water, and forms the deutoxide of hydrogen. This fluid is deprived of water, and rendered pure by precipitating the hydrochloric acid by sulphate of silver, and the sulphuric acid by barytes water, and concentrating the fluid under the air-pump. It is a remarkable substance, from the circumstance of its decomposing in contact with many bodies, such as charcoal, platinum, gold, &c., without producing any effect upon them; while certain bodies, such as selenium, arsenic, &c., are oxidized by it. The only use to which it has been applied is to clean paintings, in which white lead has been employed as a white paint, and has been turned black by exposure to smoke.

Chlorohydric Acid, Hydrochloric Acid, Muriatic Acid, Spirit of Salt, Marine Acid, H Cl; At. wt. 4·625, wt. of 100 c. i. = 39·82 or 38·68 grs. *Preparation.* — This acid is obtained in the form of a gas, which may be collected over mercury by introducing a quantity of common salt (Na Cl) into a retort with a turned-up beak (fig. 54.), and pouring on it a portion of sulphuric acid sufficient to render it pasty. On the application of heat, a gas passes over which smokes in the air in consequence of its great avidity for water. The action in this case is as follows: —

54





The sodium of the common salt unites with the oxygen of the water, and forms the oxide of sodium, or caustic soda, which then combines with the sulphuric acid, and forms sulphate of soda, or Glauber's salt. The hydrogen of the water then passes to the chlorine of the common salt, and is evolved in the form of chlorohydric acid gas.

The same gas may also be prepared by boiling in a similar retort the common muriatic acid of the shops; the gas is evolved, and is not absorbed by mercury. The gas may also be formed by mixing equal measures of chlorine and hydrogen in a green glass phial or flask, and exposing them to the action of light. They unite, and produce chlorohydric acid gas. *Characters.* The gas thus prepared is colourless, and elastic like common air, sp. grav. 1·2843 or 1·2474; when exposed to a pressure of 40 atmospheres at 50° it becomes a colourless fluid, sp. grav. 1·27. The gas reddens vegetable-blue colours; possesses a peculiar smell. When exposed to the air it combines with the moisture in the air, and assumes the appearance of fumes or clouds. When the vapour of caustic ammonia is brought in contact with this gas, dense fumes

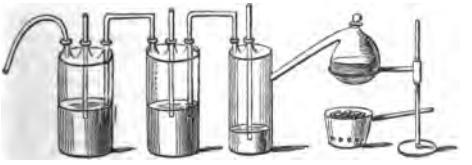
55

are formed of muriate of ammonia, or sal ammoniac. This experiment may be rendered striking by placing a portion of liquid caustic ammonia in one light flask (fig. 55.), some hydrochloric acid in another, and connecting these two flasks or phials with an intermediate flask by means of bent tubes, and then applying heat to the ammonia and chlorohydric acid. The vapour of each substance rises, and both meet and unite in the larger flask, which is filled with dense fumes of sal ammoniac (NH_3 H Cl). When an animal is introduced into this gas, life is immediately destroyed in convulsions.

The leaves of plants are also speedily corroded by it, and fall off. A lighted taper, when immersed in it, is speedily extinguished, the flame assuming a green tinge. When mixed with oxygen, and electric sparks are passed through the mixture, water is formed, and chlorine set free (H Cl and O become HO and Cl).

Liquid Chlorohydric Acid.—When this gas is brought in contact with water, 100 cubic inches of this liquid are found to absorb 41,782 cubic inches of gas. It may be prepared in considerable quantities in this liquid form by means of the apparatus recommended for the distillation of water (fig. 53.), sulphuric acid and common salt being introduced into the retort, and a quantity of water into the receiver; or the retort may be connected with a series of Woulfe's bottles, which are half filled with water (fig. 56.), and supplied with safety tubes, which, when the gas con-

56



denses too rapidly, enables the atmospheric air to enter and fill the vacuum, and thus prevents the glass vessels from being injured or the fluid retreating. These safety tubes enter by the central aperture, and dip under the surface of the water in the bottom, so as to prevent any gas from escaping. The retort may be heated by means of a gas lamp or iron chauffer filled with hot coals or charcoal, as in the figure. A portable earthenware furnace is also very convenient for this purpose (fig. 57.). The gas passes by the beak of the retort into the first bottle, where any impurities are detained, especially

57

of a liquid nature. The gas is absorbed by the water, and as soon as the water in the first bottle is saturated with the gas, what comes over afterwards passes into the second bottle by the rectangular tube, and is absorbed by the water. The latter becomes in its turn impregnated with the gas, and thus by continuing the distillation an indefinite number of bottles may be saturated with gas. The first bottle contains acid frequently contaminated with sulphuric acid, sulphurous acid, and sometimes sulphate of soda. Chlorohydric acid thus prepared is a colourless fluid, although, as it occurs in commerce, it possesses a yellow colour, from the presence of iron, bromine, or organic matter. It boils at a low temperature. Acid of 1·203 specific gravity boils at 107°; the strongest acid which can be made consists of 4·625 parts acid, and 6·75 of water (H Cl + 6 HO). When this acid is exposed to the air it gives out half its acid, and becomes then a compound of 4·625 acid, and 13·5 water (H Cl + 12 HO). Pure chlorohydric acid, when diluted with water, should afford no precipitate with chloride of barium, indicating the absence of sulphuric acid. This acid acts as a poison when taken in considerable quantities internally; but in smaller quantities it is used as a medicine alone; or with nitric acid externally, and internally, in disease of the liver, &c.

Bromohydric Acid. Hydrobromic Acid, H Br. 9·875; specific gravity 2·8125, or 2·731: a colourless gas, formed by heating together phosphorus, bromine, and a little water in a small retort, and receiving it over mercury. It smokes like hydrochloric acid gas when exposed to the air. It possesses an acid taste and reaction, acting on the skin, and is neither combustible nor respirable. It is readily absorbed by water.

Iodohydric Acid, Hydriodic Acid, H I. 15·875, specific gravity 4·409 or 4·433, is the heaviest known gas, and may be prepared by heating 1 part of phosphorus, 16 of iodine covered with moistened powder of glass, and receiving the gas over mercury. If left in contact with the mercury, the iodine combines with the metal, and sets free the hydrogen. It is rapidly absorbed by water. The solution may be prepared by mixing 40 parts of iodine and 40 of finely divided lead, with 24 of water, heating the mixture and agitating until the liquid has lost its smell. Sulphuretted hydrogen is then passed through the solution until the iodine of lead is decomposed; the solution being then concentrated by gentle heat after filtration contains hydriodic acid in solution (Pb I + SH becoming Pb S and HI). This solution becomes, by the action of the air, brown; water being formed, and iodine set free. Sometimes the iodine separates in regular octahedral crystals.

Fluohydric Acid, Hydrofluoric Acid, and Fluoric Acid, H Fl., 2·375, sp. gr. 1·06, may be obtained by heating fluorspar or fluoride of calcium (Ca Fl), reduced to powder in a lead retort along with sulphuric acid (Ca Fl. SO_3 HO become Ca O SO_3 and Fl H), and receiving it in a vessel of Fluor or Derbyshire spar, or a lead receiver. When the same experiment is made in a platinum crucible, the gas comes over, unites with water, smokes in the air, and corrodes glass. If a piece of glass be covered with bees' wax, and some figure or letters be drawn by means of a needle or nail, the glass, when exposed to the fumes of the acid, will be corroded or etched.

Theory of Hydrogen Acids.—There are two views of the state of union of hydrogen acids with bases in solution which explain the reactions equally well. Thus chlorohydric acid, when poured on lime, forms either chloride of calcium (Ca Cl) and water (HO) or chlorohydret of lime (Ca O H Cl). Others (Davy) consider H Cl a chloride of hydrogen, and that in the above compound calcium replaces hydrogen.

NITROGEN.

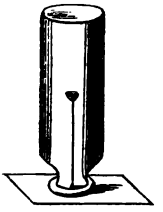
N. 1·75 ; sp. ·9722.

Mephitic Air (Rutherford, 1772). Azote, (ἀ priv. *a-* ζαω, *life*. Lavoisier, 1787). Nitrigen (Lavoisier, 1789). Nitricum, Nitric acid, (γινομαι, *I produce*). Nitrogen (Chaptal, 1790).

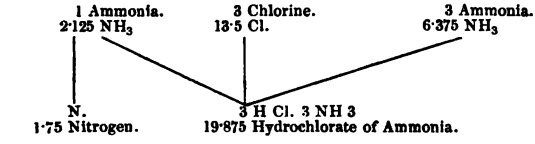
Hales in 1732 showed that a paste of sulphur and iron filings diminishes the bulk of common air. Rutherford, in 1772, proved that when an animal has breathed in atmospheric air, and the resulting carbonic acid has been absorbed, the residual air (nitrogen), extinguishes flame and life.

Preparation.—Nitrogen may be prepared: 1. By inverting a jar of common air over water, on a stand, connected with a wire and cup (fig. 58.). A piece of phosphorus is placed on the latter, and fired; the jar is inverted over it; the oxygen is consumed, and its place is supplied by water, which rises so as to fill one fifth of the jar, and thus measures the bulk of oxygen contained in common air. The experiment may also be conducted by swimming a cork on the water, on which a piece of copper foil is placed; the phosphorus is ignited on the foil, and the jar inverted over the cork. As the combustion goes on the cork rises in the jar, followed by the water.

58



2. Another simple process consists in passing chlorine gas through caustic ammonia (NH_3). Chlorine is evolved in the first flask from black oxide of manganese and hydrochloric acid, and passes into a second flask partially filled with ammonia. The chlorine combines with the hydrogen, and sets the nitrogen free, thus : —



If the ammonia is very strong, slight explosions occur, which however may be avoided by diluting it.

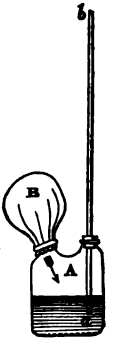
3. It may also be prepared by filling a small retort with a paste of bleaching powder, and dropping into it pieces of sal ammoniac; nitrogen escapes in abundance (T. Thomson).

Characters. — Nitrogen is a colourless gas, destitute of taste and smell; sp. grav. ·9722 (Thomson and Dumas), but about 854 times lighter. than water; neither combustible nor respirable;

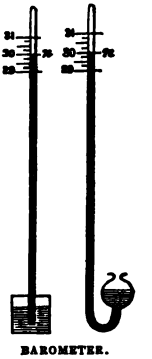
100 cubic inches of boiled water absorb $1\frac{1}{2}$ inch of nitrogen. It has never been condensed. Wt. of 100 c. i. = 30·15 grains.

Common air, or atmospheric air, is a colourless compressible mixture of oxygen and nitrogen gases surrounding the surface of the earth. Its compressibility may be exhibited by placing some coloured fluid in a two-necked bottle, adjusting a tube to one mouth through a cork, as in the figure, and tying a bladder blown full of air to the other mouth. On compressing the air in the bladder with the hand, the liquid rises in the tube (fig. 59.).

59



60



BAROMETER.

From observations with the barometer it has been inferred that a stratum of air reaching from the earth's surface to the height of four miles, contains at all times above one half the whole matter existing in the atmosphere, and that a stratum of 12 or 13 miles high contains $\frac{19}{20}$ths of the whole; or if a barometer standing at 30 inches were elevated to that height, the mercury would fall 29 inches.

The weight or pressure of the atmosphere is estimated by taking a dry tube (fig. 60.), 31 inches long, closed at one end, with the open end upwards, and filling it with clean boiled mercury, placing the finger on the open end so as to retain the fluid, and then inverting it in a small cup or basin, filled with mercury. It will be found that, although 31 inches of mercury have been placed in the tube, the mercury will subside, and leave a vacuum at the top of the tube proportionate to the atmospheric pressure. The atmospheric pressure at the level of the sea, is capable of supporting a column of mercury of 30 inches, or a column of water of $34\frac{1}{2}$ feet; and hence the pressure upon every square inch of surface on the globe, when the barometer is at 30 inches, is 15lbs. But since the pressure diminishes as the density of the air is lowered, it is obvious that if the pressure on a man's body at 30 inches be $14\frac{1}{2}$ tons, this weight must greatly diminish when the barometer falls; so that we may have changes in pressure to the amount of $1\frac{1}{2}$ or more tons upon the human body, a probable cause of disease. The rarefaction of the air, as we ascend in the atmosphere, so rapidly increases, that at the height of 500 miles it may be shown that air occupying the space of a cubic inch, at the surface of the earth would expand so as to fill a sphere equal in diameter to the orbit of Saturn. The density of air at various altitudes is shown in the following table.

Miles.	Vols.	Miles.	Vols.
0	1	10·82	16
2·705	2	13·525	32
5·41	4	16·23	64
8·115	8		

It is upon this principle that we are enabled to measure the height of an elevation above the sea. By ascertaining the height of the barometer at the top of a hill, and that of another at the level of the sea at the same time, and taking the logarithms of these numbers, we obtain a close approximation to the height of the place. Thus at the sea the barometer stood at 29·82 inches; at the top of a hill at 29·309 inches. The logarithm of the first number less that of the second gives the height; or 1·4750 — 1·4670 = 80 fathoms. By means of the thermometer we can also deduce the height of the barometer, and therefore the height of a station. Thus the boiling point of water diminishes 1° of Fahrenheit's thermometer for every 549½ feet of ascent. By boiling water, therefore, in an open pot on the summit of a mountain, and taking the temperature of the boiling water, we can easily calculate the height of the mountain; at 30 inches the boiling point of water is 212°.

The atmosphere consists of nitrogen, oxygen, carbonic acid, and vapour of water dispersed equally through each other. The mode in which this dispersion takes place may be illustrated by filling one bottle with common air, another with carbonic acid, connecting the first with the mouth of the last by a tube and perforated cork, so that the interior of the two bottles may be contiguous (fig. 61.). In a short time we shall find that the carbonic acid, although much heavier than common air, has ascended into the upper bottle, and diffused itself so equally, that on pouring in lime water into both bottles, an equal amount of carbonic acid can be detected in both. This has been accounted for by supposing that the two gases, passed into the bottles, disperse through each other as if into a vacuum (Dalton). The composition of the air is as follows, by measure and weight, according to Cavendish, and confirmed by Dumas, in every hundred parts: —

61

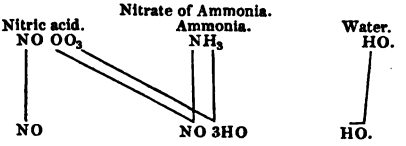
Nitrogen, by bulk, 79·20; by weight, 77. Oxygen, by bulk, 20·80; by weight, 23; 100 c.i. weigh 31·0117 grs. (Prout.) 100 vols. of water dissolve 3·2 air.

The amount of carbonic acid is 4 parts by bulk in 10,000 volumes of pure air. When the amount of this acid much exceeds this proportion, the air may be considered vitiated and unhealthy. In crowded rooms it sometimes collects to the extent of 1 per cent., when great oppression is generally experienced by the audience. An atmosphere containing 3 per cent. of carbonic acid is dangerous.

The particles of air, and of all gases, separate further from each other when heat is applied to them. Thus, in summer, there are less oxygen and nitrogen in a given space than in winter; hence heated air is lighter than cold air, and it ascends. It always happens, therefore, in rooms artificially heated, that the air near the fire becomes hot and ascends, while its place is supplied by cold air from the door and windows. A draught of air is thus continually kept up from the lower to the upper part of a room, upon the proper regulation of which the ventilation of apartments depends. Illustrations of this fact may be obtained in various ways. A thermometer at the top of a warm room stands higher than one below. A lighted candle at the bottom of a door has its flame blown towards the room, while at the top of the door it is blown outwards. Soap bubbles in hot weather ascend out of doors. In a warm day the shadow of any object thrown on a bank or over a level plain at a distant land mark is obviously influenced by an ascending current of air. It is this current probably which buoys up the fine lines projected by spiders, and thus enables them to move from one object to another.

Protoxide of Nitrogen. — NO 2·75; sp. grav. 1·5277. Dephlogisticated nitrous air (Priestley, 1776). Nitrous oxide. (Davy, 1800). Oxidized azote, Laughing gas. Protoxide of Nitrogen or Azote (Thomson).

Preparation. — This gas may be prepared from nitrate of ammonia, a salt formed by saturating carbonate of ammonia with nitric acid, and crystallizing the resulting nitrate of ammonia. The nitrate is introduced into a retort (fig. 54.), and heated up to the temperature of 400°; it speedily melts, and evolves the gas in great abundance, according to the following scheme: —

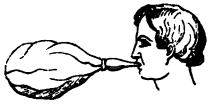


Where we have an atom of nitric acid and an atom of ammonia resolved into two atoms protoxide of nitrogen and three atoms of water, or 10 grs. of the salt, afford 5½ of the gas.

Characters. — Protoxide of nitrogen is colourless, possesses the mechanical properties of common air, and a peculiar, agreeable odour and sweet taste; spec. grav. ·9722 + ·5555 = 1·5277; and hence it consists of 1 vol. nitrogen, and ½ vol. oxygen condensed into one volume; 100 cubic inches of it weigh 47·375 grs. By a pressure of 50 atmospheres it becomes liquid, and at 148° in a

vacuum solid. 1. It is not a combustible body; but when a taper is introduced into it the combustion is supported with great brilliancy, in consequence of the oxygen which it contains. 2. A splinter of wood, ignited and then blown out, and glowing when introduced into it, is relighted, as in the case of oxygen. 3. Phosphorus, when touched with a hot wire, or previously ignited, burns with great brilliancy in this gas. 4th, sulphur; and 5th, iron, burn as in oxygen, but more briefly. 6. Charcoal burns in nitrous oxide when ignited by a burning glass. 7. *Its effects on animals* are remarkable. When a rabbit is introduced into the gas, it exhibits no symptoms of uneasiness for some time; but in the course of a minute or two it becomes excited, pants, falls prostrate, and dies. On man its influence varies according to the constitution. On some it produces symptoms of stupor, which lasts for a few seconds. Others, after a few inspirations, fall senseless. From this state they speedily recover with confused ideas and headache. Another class are affected with pleasurable sensations; they laugh and skip about as if intoxicated; or a pugnacious disposition is excited, which renders the objects of the experiment for the time rather unpleasant companions. The best method of breathing the gas is to use a bladder supplied with a wooden mouth-piece. The bladder is softened in water, and filled from the gas-holder containing the nitrous oxide by the side aperture of the apparatus, or on a smaller scale it may be filled over the water trough. The mouth-piece is then placed between the teeth (fig. 62.), the nostrils closed by the forefinger and thumb, and the gas inhaled as in common inspiration. It is proper on such occasions to remove all apparatus, lest they should be injured by the violence of the inhaler. It is advisable to allow the gas to stand for some hours over water to absorb any *hyponitric acid* which might be formed in the decomposition of the nitric acid. 100 water dissolves 50 NO.

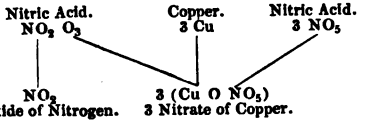
62



Deutoxide of Nitrogen, NO_2 3·75; sp. grav. 1·04166; discovered by Hales about 1725; called *nitrous gas* by Dr. Priestley in 1772. It was afterwards called *nitric oxide, deutoxide of Azote.*

Preparation. — This gas enters into the composition of nitric acid, the constitution of which may be represented by the symbol $NO_2\,O_3$. To liberate the NO_2, or deutoxide of nitrogen, we have only to bring in contact with the acid a simple substance which has a great affinity for oxygen. This substance is a metal; thus, if we dilute nitric acid by adding water to it till it attains the specific gravity 1·2, and pour it upon metallic copper in a retort or flask, supplied with a bent tube (fig. 67.), the deutoxide rapidly escapes, the copper is oxidized at the expense of a portion

of the acid, while the oxide formed unites with another portion of the nitric acid.



Characters. — Deutoxide of nitrogen, is a colourless gas, similar to atmospheric air in appearance. When it comes in contact with air, it unites with an additional dose of oxygen, and forms orange fumes of hyponitric acid (NO_4), which are highly corrosive; specific gravity 1·111 + ·9722 ÷ 2 = 1·04166 or 1·039. The weight of 100 cubic inches is 32·303 grains. It is a noncumbustible, but a supporter of combustion. Refracting power 1·03.

Similar *experiments* may be performed with this gas as with oxygen and nitrous oxide, to illustrate the power which it possesses of supporting combustion. 1. Thus burning phosphorus, potassium, glowing charcoal burn in it. 2. If some drops of sulphuret of carbon are poured into it, combustion occurs with deposition of sulphur. 3. When mixed with hydrogen it burns with a green coloured flame. 4. When a solution of sulphate of protoxide of iron (copperas), is exposed to the action of this gas, (which may be exhibited by evolving the gas from a flask with bent tube, fig. 63.) passing it through the solution, the latter becomes black, and the quantity of oxide absorbed is sufficient to convert the oxide into a sesquioxide salt; but almost the whole of the gas may be expelled by heat. Nitric oxide is one of the best tests of the presence of oxygen, since wherever these gases are brought in contact red fumes of hyponitric acid (NO_4) are produced; but air cannot be accurately analysed in this way, as the amount of condensation constantly varies, depending upon the formation of a mixture of two compounds (NO_3 and NO_4). 100 vols. water dissolve 5 NO_2.

63

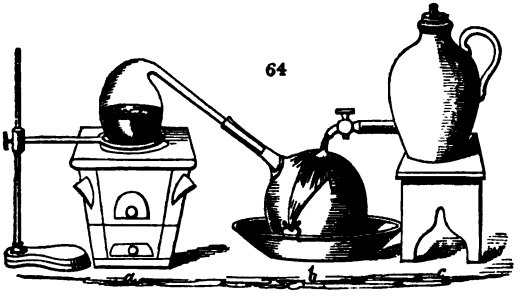
Ternitrous Acid, 4·75, NO_3; *Nitrous Acid*; *Hyponitrous Acid*; *Azotous Acid.* — If nitrate of potash be heated in a porcelain crucible till it disengages oxygen, and gives a white precipitate with nitrate of silver, the precipitate thus formed consists of oxide of silver and nitrous acid (Ag O NO_3). It may be also obtained by passing 4 vols of deutoxide of nitrogen, and 1 vol. of oxygen from two gas-holders into a long tube, terminating in a small flask, which is surrounded with a mixture of snow and chloride of calcium. A very volatile liquid condenses which can only be preserved in hermetically sealed vessels; it is colourless at 4°, but green at the usual temperature of the air. When brought in contact with water it is converted instantly into nitric acid and deutoxide of nitrogen (3 NO_3 becoming 2 NO_2 NO_5). The nitrites of soda, barytes and strontian may be obtained in crystals, by

forming first, nitrite of soda, heating this with nitrite of silver, and decomposing the nitrite of silver by the metallic chlorides.

Quadrinitrous Acid (NO_4) 5·751 ; *Hyponitric Acid ; Nitrous Acid ; Azotous Acid* (Scheele, 1774) ; is formed when we mix 2 volumes of deutoxide of nitrogen with 1 of oxygen ; ruddy fumes are produced, which consist of 1 atom of nitrogen and 4 of oxygen. It is always formed when we act upon metals by nitric acid. $3\ M + NO_5\ O_3\ 3\ NO_5$ becoming $3\ MO + 3\ NO_3 + NO_3$. The NO_3 then unites with 2 atoms of oxygen from the air, and forms NO_4. When we heat nitrate of the oxide of lead in a retort, we can collect an orange-yellow liquor in the receiver, if it be surrounded with a freezing mixture ($PbO\ NO_5$ becomes $PbO\ NO_4 + O$). It reddens litmus, boils at 82½, nearly colourless at 14°, fawn at 32°. Specific gravity 1·451.

Nitric Acid, 6·75 (NO_5) ; *Acid Spirit of Nitre ; Azotic Acid* or *Aquafortis* was known to Geber in the seventh century. It exists in union with potash, in India, as nitrate of potash ; in South America, as nitrate of soda. It may be formed by passing electric sparks through common air. Nitrate of ammonia has been detected in rain water. Anhydrous nitric acid is unknown.

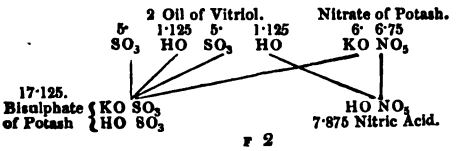
Preparation. — Nitric acid is prepared from nitrate of potash, or nitrate of soda. When nitre is used, we mix in a retort equal weights of that salt and oil of vitriol of commerce. The resulting products are nitric acid, which passes into the cooled receiver, and bisulphate of potash, which remains in the retort in a liquid form while hot,—a white saline mass when it has become cold. Two atoms of SO_3 are used, otherwise the NO_5 decomposes.



a, Retort containing the materials for producing the acid, supported on a stand over a furnace heated with charcoal.

b, A receiver kept cool by a current of cold water supplied from *c*, a stoneware jar.

The action is as follows —



From 12¼ parts of oil of vitriol (HO SO_3) and 12¾ parts of nitre we ought to obtain 7¾ parts of nitric acid. When nitrate of soda is used, we mix 12¼ parts of sulphuric acid in the retort with 10¾ parts of nitrate of soda.

Characters.— Nitric acid exists in combination with 2 proportions of water. 1. The protohydrate of nitric acid (HO NO_5) consists of an atom of water and an atom of acid, or contains 86 per cent. of acid, and 14 of water, the boiling point being 186¾°, and the spec. grav. 1·522. 2. Quater hydrate. The second hydrate consists of four atoms of water and one of nitric acid, or 60 per cent. nitric acid and 40 water. The boiling point is 253½°, and the spec. grav. 1·422. Other two hydrates have been described, but their existence is still doubtful. One of them contains two atoms of water, and the other 4½ of water to one of nitric acid (2 HO NO_5 and 4½ HO NO_5). The protohydrate may be obtained by distilling 1½ lb. of nitre, 1½ of sulphuric acid into a receiver containing 7¼ ounces of distilled water, the receiver being kept cool with a current of cold water dropping upon it. The second hydrate (4 HO NO_5) is procured by adding one fifth of its bulk of water to the protohydrate (HO NO_5) in a retort and distilling. The second hydrate passes into the receiver, and is the strong nitric acid of commerce.

1. Nitric acid readily acts on bodies, in consequence of the facility with which a portion of its oxygen unites with substances. It thus acts on organic matters, and is said, in common language, to corrode. When first prepared in a pure state it is a colourless fluid, but when it is exposed to the light it becomes yellow, giving out oxygen. It smokes when exposed to the air, has a peculiar odour, an intensely acid taste, and reddens vegetable blues. When brought in contact with the skin it unites with the gelatinous matter of which it is composed, and turns it yellow. On account of its ready action on animal matter it is used to cure deep and foul ulcers, to which it tends to give a clean and healthy surface. It is also used internally and externally in the form of bath in liver complaint. 2. It is from the facility with which it parts with three of its atoms of oxygen that its property of oxidizing metals arises. Three atoms of oxygen readily pass to the metal, while deutoxide of nitrogen is evolved; so that the formula for nitric acid might be represented to be NO_2 O_3, as appears under deutoxide of nitrogen. This constitution is exhibited when any of the metals are brought in contact with diluted nitric acid. 3. If we wrap up nitrate of copper with a drop or two of water in tin-foil, heat and light are evolved, and the tin is converted into peroxide of tin, at the expense of three atoms of oxygen, deutoxide of nitrogen being evolved. 4. If we heat

gently some oil of turpentine in a porcelain basin, and then pour upon it a mixture of one part sulphuric acid and two parts of nitric acid, a beautiful combustion takes place, with the evolution of much smoke. In this experiment the mixture often sparks about; it is therefore advisable to pour the acid from a glass tied to the end of a stick three or four feet long (fig. 65.).

65

The action depends upon the union of the oxygen of the nitric acid with a portion of the carbon of the turpentine. 5. *Gun cotton.*— When cotton wool is boiled in a solution of caustic soda or potash, well washed, dried, and carded,—then immersed for a minute in a mixture of equal bulks of sulphuric acid and the strongest nitric acid ($HO\ NO_5$), termed fuming nitric acid, a portion of the acid unites with the cotton, and forms an explosive compound. After immersion for one minute in the acid, with which it is to be thoroughly impregnated by means of a glass rod, a stream of water is to be allowed to fall upon it, until the acid taste is removed. It is then pressed in a cloth, and allowed to remain in dry air slightly heated to remove all the moisture attached to it. When this substance after drying is touched with a hot iron which is still black, an instantaneous explosion is produced, and no residue is left, the gases evolved being principally carbonic oxide and nitrogen. The composition of gun cotton is $C_{12}\ H_7\ O_7 + 3\ NO_5$ (Crum). The common aqua fortis, of spec. grav. 1·33, does not answer for the production of this substance. 6. Nitric acid forms soluble salts with all bases. Many of the crystallizable salts contain six atoms of water, as nitrate of magnesia = $Mg\ O\ NO_5\ 6\ HO$. There is, however, great irregularity in their composition, and their true theory appears yet a desideratum. *Tests for nitric acid.*—1. When gold leaf is added to nitric acid no change takes place; but if a drop or two of hydrochloric acid be mixed with it, the gold leaf disappears even without the application of heat. This mixture is termed aqua regia or royal water, because it alone is capable of dissolving the royal or noble metals, gold, platinum, &c. According to Davy, these two acids react upon each in this experiment, and free chlorine is evolved, which dissolves the gold. According to Millon nitrous acid (NO_3) is formed in this mixture, and is the cause of the solution. The NO_3 is produced by the action of NO_2, evolved by the oxidation of the metal upon NO_5. The presence of nitrites in hydrochloric acid answers as well as nitric acid. 2. Another test for nitric acid, when in union with a base, is to pour a few drops of sulphuric acid on the compound in a tube, and apply heat; the odour of the acid and red fumes of hyponitric acid (NO_4) may be easily recognised. 3. A delicate test is to add a few drops of a strong solution of sulphate of prot-

oxide of iron (green vitriol) to a concentrated solution of the suspected nitrate. Pour in a dram of sulphuric acid, pure and free from NO_2. If nitric acid is present, a dark line will be seen at the point where the two fluids meet, produced by the evolution of NO_2.

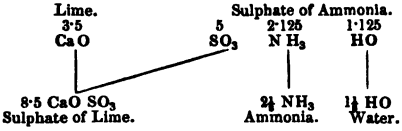
Uses.—Nitric acid is used in surgery as an application to sores. It is used to convert sugar into oxalic acid in the manufacture of the last substance. It is employed in agriculture in the form of nitrates of potash, soda, &c., with very beneficial action, especially for hay crops.

Chloride of Nitrogen.—The exact composition is unknown; it is supposed to be NCl_4; sp. grav. 1·653 (Dulong). To prepare it, dissolve in water of 110° a quantity of nitrate of ammonia, or sal ammoniac, so as to produce a strong but not a saturated solution of the salt. This solution is placed in a flat metallic vessel or saucer, and over it is inverted a jar of chlorine gas. The gas is slowly absorbed, and on its surface swims a yellow oil, which as it increases falls to the bottom. When touched or agitated this oil explodes with great violence, so that only a limited quantity of it should be made at a time.

Iodide of Nitrogen (NI_3?), (Courtois), can easily be prepared by adding caustic ammonia to a solution of iodine in alcohol as long as a brown precipitate falls. This precipitate, which is the iodide of nitrogen, is to be thrown on a filter, and as soon as the liquid has passed through, the filter is to be spread out on a plate of iron or porous brick until it is dry. It is then a dark brown powder, which when touched with a stick explodes. Sometimes it requires to be struck with a hammer on an anvil, when it detonates with great violence. Care should be taken in its preparation, as it sometimes explodes even when moist. It has been conjectured that both this substance and the preceding may contain amidogine NH_2, (Dumas).

Ammonia; Spirits of Hartshorn, Volatile Alkali, Alkaline air, NH_3 2·125.—The word Ammonia, as occurring in Dioscorides, refers to common salt. Tournefort, in 1700, was aware that sal ammoniac consisted of an acid and ammonia. Priestley first described caustic ammonia as a gas. *Preparation.*—Ammonia occurs in the air and soil in the form of carbonate of ammonia; as sal ammoniac ($NH_3\,HCl$) in the fluids of animals; in some minerals containing iron and alumina, and may be produced by exposing moist iron-filings to the action of common air in a close vessel. It is evolved from animal substances by the action of caustic potash, or soda. The great source of ammonia in commerce is the liquor of gas works, which contains carbonate of ammonia. As the carbonate is volatile it may be fixed by sulphuric or hydrochloric acids. To prepare the pure gas from these salts, they are mixed with quick lime in a retort, to which

heat is applied; the gas must be collected over mercury. The action is as follows: —



Characters. — Ammonia is a colourless gas possessing the mechanical properties of common air; its taste is caustic, blistering the tongue and mucous membrane of the mouth; it cannot be respired unless in a very dilute state; its sp. grav. is ·9722 + ·2088 ÷ 2 = ·5902; 100 cubic inches weigh 18·308 grs. In consequence of its volatility it is much used in the form of *smelling salts*. These may be formed by mixing 1 part of sal ammoniac with 2 parts of lime moistened with water in a closely stoppered-bottle. When exposed to a pressure of 6½ atmospheres, ammonia becomes a fluid, or at a temperature of —40°.

Ammonia and Water, Caustic Ammonia, Liquid Ammonia, Hartshorn. — Ammoniacal gas is absorbed in great abundance by water. A current of ammonia, when passed through 6 cubic inches of water, is absorbed to the extent of 780 times the volume of the water, while the bulk of the water increases to 10Ci; hence 1 cubic inch of water absorbs 468 of ammonia. To prepare caustic ammonia, equal parts of slaked lime and sulphate or muriate of ammonia are mixed in a retort, either of glass or iron; water is added till the mass is formed into a paste. The retort is then connected with a series of Woulfe's bottles, as described and figured under hydrochloric acid (fig. 56.). In the first bottle a small portion of water is placed to remove the impurities; the second and third bottles are half-filled with water. The retort is placed in a sand-pot, as with nitric acid, and distilled with a gentle heat; when the water is thoroughly impregnated its sp. grav. is 0·872, and it contains 32½ per cent. of ammoniacal gas.

Tests. — If pure, caustic ammonia should leave no residue when evaporated to dryness. When neutralised with pure nitric acid it should not precipitate acetate of lead (sulphuric acid), or nitrate of silver (H Cl). To estimate the amount of ammonia in a solution, we add hydrochloric acid, then a solution of bichloride of platinum, and a mixture of alcohol and ether; the yellow ammonia bichloride of platinum falls (NH_4 Cl Pt Cl_2), every 28 grains of which contain 2·125 of ammonia. When the stopper of a muriatic acid bottle is held over ammonia, white fumes of sal ammoniac are formed. This may be shown by connecting two flasks, one containing hydrochloric acid and the other caustic ammonia, with a centre flask, by means of bent

tubes, as in the figure for exhibiting the theory of sulphuric acid (or fig. 55.). On the application of heat to the side flasks, ammonia and hydrochloric acid are evolved, and unite in the middle flask, where they form dense white clouds of sal ammoniac. Ammonia may also be detected by the brown colour which it communicates to turmeric paper moistened. Paper moistened with an alcoholic solution of parietin (a colouring matter extracted from the common wall lichen by alcohol) is coloured pink by ammonia.

Salts of NH_3. — All the oxygen acid salts of ammonia contain an atom of water; the formula for nitrate of ammonia is $NH_3 NO_5 HO$; and of sulphate of ammonia $NH_3 SO_3 HO$. The carbonate of the shops is a sesquicarbonate, consisting of $2NH_3 3CO_2 2HO$. Ammonia unites with many salts which have been deprived of water, and seems to perform the functions of water. Sulphate of magnesia absorbs 2 atoms, sulphate of nickel 3.

Uses. — Ammonia is a most important body in chemical analysis, from its action upon oxides. (See Tables on *Tests.*) Ammonia is used as a blistering agent in medicine. As a stimulant it is administered in water by the stomach. In sore throats it is mixed with olive oil (1 ammonia, 2 oil), and applied externally, under the name of volatile liniment; when held to the nostrils it acts as an antidote to prussic acid, and to recover from fainting. It enters into the composition of ammoniacal alum, and is of great value as a manure in agriculture, as plants readily assimilate nitrogen in this form. Guano owes its value to the nitrogen and ammonia which it contains. The urine of animals is another fertile source of ammonia, the urea which that fluid contains being converted by standing into 2 atoms of carbonate of ammonia by the assumption of 2 atoms of water; this last salt being volatile, the ammonia must be united with sulphuric acid. This is effected by collecting the urine in a tank, and adding to it common oil of vitrol. Liebig considers that the nitrogen of plants reaches them from the air in the form of ammonia, which falls to the earth with the rain, and gains access by the roots.

Theories of $N H_3$. — 1. *Ammonia Theory.* By this view ammonia is considered as a gas, and combines directly with acids. With $S O_3$ it forms $NH_3 SO_3 + HO$. With Cl it forms sal ammoniac, NH_3 Cl H. 2. *Ammonium Theory.* If we rub in a mortar a small portion of sodium, with some mercury (filtered through leather or paper), until an amalgam is formed, and then drop it into a strong solution of sal ammoniac in a tube, the amalgam swells and rises up in the tube to an extraordinary height. This increase of volume is supposed to be owing to the union of ammonium (NH_4) with the mercury. $Na + Hg$, and $NH_4 + Cl$ becoming Na Cl and Hg NH_4. According to this view, the ammoniacal salts are no longer compounds of the gas with an acid, but of acids with the aid of a metal; sulphate of ammonia being $NH_4 OSO_3$. 3. *Amide Theory.* According to

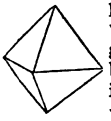
this theory ammonia is an amide of hydrogen ($H + NH_2$). This is proved by passing dry ammonia over potassium in a tube at a red heat; a green substance is formed called potassamide (KNH_2), and hydrogen is liberated. Sulphate of ammonia is, upon this view, HNH_2, HO, SO_3.

CARBON.—*Charcoal.*

C. ·75. The most familiar form of carbon is charcoal, which has been known from a very early period of history. The term coals, mentioned in Isaiah (liv. 16.) 712 years before Christ, obviously refers to charcoal. Carbon occurs in various forms.

1. The *diamond* is perfectly pure carbon crystallized as an octahedron, or an eight-sided figure, consisting of two pyramids applied base to base, the eight faces of which are equal-sided (equilateral) triangles; sp. grav. 3·4 to 3·6, hardness 10, and is not scratched by any substance in nature. Diamonds are found in the debris or decayed portions of the rocks which were deposited before the existence of animals on the earth — in Brazil and India. The Pitt diamond, in possession of the late King of France, weighs 419 grains, and its estimated value is half a million of pounds sterling. When the diamond is heated in a stream of oxygen playing on a lamp, intense light is produced, the diamond unites with oxygen, and is converted into carbonic acid (CO_2).

66



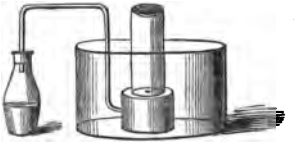
2. *Plumbago, Graphite*, or *Black Lead*, familiarly known in black lead pencils, is another form of carbon, sp. grav. 1·9 to 2·32, occurring in pieces about the size of the fist in the Graywacke rocks of Keswick. The purest black lead consists of 95 per cent. of carbon, 3 of water, and 2 of iron and manganese. It is sawn into slices for use, and is fitted into the grooves of *cedar pencils*, or rounded for *ever-pointed pencils*. Plumbago is much used to prevent friction, and its power in this way may be exhibited by rubbing a button smartly on the table where powdered plumbago has been strewed, and another button on the bare table. In the former case little or no heat is generated, while in the latter case the heat is sufficient to inflame phosphorus. 3. *Wood Charcoal* is often formed in this country in the distillation of wood for the preparation of vinegar; the charcoal remains in the iron still. It is formed on the continent by piling up branches of trees, covering them with turf, and setting them on fire. They are converted into carbon by slow combustion. The purest charcoal may be obtained by burning sugar, gum, or glue. Black crayons are made from willows for drawing purposes. Sp. grav. 3·5. It absorbs fluids and gases with great facility. 4. *Animal Charcoal* or *Ivory Black*, is prepared by burning bones deprived of their fat and

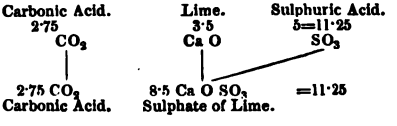
grease in cast-iron cylinders; the bones give out a quantity of gas, and fluid containing ammonia, which distils off, while the carbon and bone earth remain. It is used to remove colours from fluids, as in sugar refining, and disagreeable odours from water and putrid fluids. The first experiment may be easily shown by digesting brazil or barwood in hot water, filtering the liquid, and shaking it with animal charcoal, and then filtering; the fluid passes through colourless. 5. *Lamp black* is made by burning fir, rosin, or tar, and collecting the smoke; it is used for printers' ink. 6. *Anthracite, Welsh culm*, is a kind of hard coal, found in Wales and other places, which contains upwards of 90 per cent. of carbon. 7. *Coal* or *Pit coal* is well known under the names of *cannel, parrot*, or *gas* coal, *caking* or Newcastle coal, *cherry* and *splint* coals. These are all supposed to have been originally converted from wood into their present forms by heat and pressure; they contain from 65 to 85 per cent. of carbon.

Carbonic Acid. — CO_2 2·75. *Fixed air* (Black, 1755.) *Chalk acid* (1777). Specific gravity 1·5277. Weight of 100 cubic inches 47·376. Refracting power 1·526.

1. Carbonic acid may be prepared from marble, chalk, or limestone, or any carbonate, by introducing them in fragments into a retort or gas bottle (fig. 67.), supplied with a bent tube, and pouring in hydrochloric or sulphuric acids. The gas passes over in torrents, and may be collected over water, although it is very soluble in that fluid. The action in this experiment is as follows: —

67





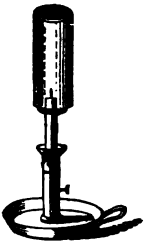
The production of carbonic acid may be familiarly illustrated by placing chalk in the bottom of a wine or ale glass, and pouring upon it strong vinegar or hydrochloric acid; the glass will soon be filled with the gas. 2. Carbonic acid is produced in the most familiar cases of combustion, as when wood and coal are burned; the carbon of the combustible body uniting with the oxygen of the air to form this gas.

Characters. — It is colourless and transparent like common air. When brought in contact with the nostrils, a pungent sensation

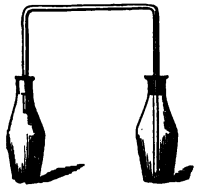
is produced. Carbonic acid may be proved to contain carbon by heating slices of sodium with chalk in a German glass tube over a gas flame, a detonation takes place, and the mixture becomes black by the deposition of carbon (Ca O CO_2 and 2 Na becoming CaO, C and 2 NaO).

Experiments.—1. Its taste is distinctly sour. 2. It colours infusion of litmus and moistened litmus paper red; the colour being restored by exposure to the air. 3. Carbonic acid is neither a combustible nor a supporter of combustion. When a jarful of it is poured upon a lighted taper the flame is extinguished (fig. 68.). This property may be compared with that of oxygen by having a jar filled with oxygen alongside of the carbonic acid jar. 4. If the upper half of a tall jar open at both ends be filled with oxygen, and then the lower part be filled with carbonic acid from a retort, a taper, when introduced into the jar, burns brilliantly in the upper half, and is extinguished in the lower part of the jar. The extinction and relighting of the taper, repeated frequently, has a fine effect. 5. The great weight of carbonic acid is shown by experiment 3. It may be further illustrated by passing the gas from a flask and bent tube into a jar filled with common air. The carbonic acid, from its great weight, falls to the bottom, and presses up the common air by replacement (fig. 69.). In consequence of the weight of the gas, it remains for some time in contact with the earth when it is emitted in nature, as in the Dog's Grotto near Naples, and in the Upas valley in Java. The presence of 5 or 6 per cent. of CO_2 in air extinguishes a candle. Hence it is usual to test the salubriousness of air in mines by lowering a candle or lamp into the tainted atmosphere. If the candle goes out the conclusion is drawn that human life would also be extinguished; but if the candle burns it is inferred that the miner may proceed to his work in safety. 6. If we place some water in a bottle containing CO_2 and then agitate it, closing the mouth tight with the finger, we shall find that the finger is sucked in, and that if we remove the finger under water, a new portion of fluid will forcibly enter. This is owing to the absorption of the gas by the water. It has been found that a bottle full of gas will be taken up nearly by the same bottle full of water. Hence it is said that water absorbs its own bulk of it, or 100 volumes absorb about 107 volumes of

68



69



gas. It is upon this principle that soda water is made, which consists simply of water into which CO_2 is forced by pressure. The presence of carbonic acid may be proved in soda-water after it has stood for some time by throwing into it pounded sugar and stirring it well. The CO_2 is pushed out by the sugar which takes its place. 7. Its presence may also be shown by adding lime water (prepared by mixing quicklime previously slaked with water, and pouring off the clear liquid) when carbonate of lime falls. 8. If a current of gas be now passed through the water containing this precipitate, the latter will dissolve, and assume the condition which lime possesses in well water, as explained by this diagram: —

$$CaO\ CO_2 \quad \text{Carbonate of lime, insoluble in water} \quad CO_2 \quad \text{Bicarbonate, soluble in water.}$$

We can again succeed in precipitating the lime by adding some more lime water. 9. Carbonic acid is capable of being condensed into a liquid, and also into a solid form resembling snow, by pressure, in a strong iron apparatus contrived for the purpose; as the performance of this experiment requires great precaution, and is attended with much risk, it seems unnecessary to describe it here. 10. That carbonic acid is produced in cases of combustion can be proved by placing a lighted candle under a jar along with some lime water. Carbonate of lime is formed. 11. The same gas is produced in the lungs; for if we breathe through lime water by means of a glass tube or the stalk of a tobacco pipe, carbonate of lime is thrown down in a milky form, the precipitate effervescing in acids as muriatic acid or vinegar. 12. That CO_2 is produced in germination, and that the oxygen of the air disappears, may be shown by putting a few beans into a small quantity of water in a phial, which is then corked and sealed with wax. In a week or two the air of the phial will be found to extinguish a taper. A sprig of mint placed in this air will remove the CO_2 and restore the oxygen. 13. What is usually termed *effervescence* (from *effervescens*, boiling) is produced by the rapid escape of this gas, as in champaigne and fermented liquors (ale, porter, beer, &c.), when they rise in bubbles when poured out; if carbonic acid is absent they are said to be *flat*.

Weighing CO_2 *in Carbonates.*—The simplest method, and perhaps the most delicate, is to introduce into a small flask, weighing about 300 grs, a quarter ounce measure of sulphuric acid, and half an ounce of water. Weigh out in a small tube weighing 30 or 40 grs., the weight being accurately noted, 50 or 100 grs. of the carbonate to be examined; suspend it by a thread in the

flask, and close the flask by a perforated cork and tube containing chloride of calcium. Then weigh accurately the whole apparatus. Lower down the suspended tube into the fluid, and gradually by agitation wash out the carbonate from the tube. After effervescence has ceased, heat gently the flask, release the cork slightly, apply a suction tube to the top of the chloride of calcium, and draw out the air from the flask. Then weigh the apparatus. The loss indicates the carbonic acid in the carbonate used.

70

Carbonic Oxide. CO 1·75. Sp. gr. ·9722. Weight of 100 cubic inches 30·149. Refracting power 1·157.

Process. — First observed by Priestley in 1772, but accurately described by him in 1800. (1.) It may be procured by passing carbonic acid through a red hot tube filled with charcoal; CO_2 and C becoming 2 CO. (2.) When oxide of zinc and charcoal are heated in an iron bottle similar to that employed in making oxygen, carbonic oxide is produced; ZnO and C becoming Zn and CO. (3.) The same gas is also obtained by heating the carbonates of lime, barytes, &c. with charcoal; CaO CO_2 and C becoming CaO 2 CO. (4.) Carbonic oxide may be prepared abundantly by pouring sulphuric acid on the yellow prussiate of potash in a retort (Dr. Thomson, 1818). (5.) The simplest process, however, for preparing carbonic oxide is to mix pounded oxalic acid (CO + CO_2 + 3 HO) with sulphuric acid in a retort, and apply heat. The acid removes the water, and sets free the carbonic oxide and carbonic acid which pass over, and can be collected over water. By standing or agitation the CO_2 is dissolved and the CO remains; but the combustible properties of the gas may be examined in the mixed state.

Characters. — Carbonic oxide is colourless, and without smell.

Experiments. — (1.) When a taper is brought to the mouth of a jar containing it, the gas catches fire, and burns with a fine blue flame; (2.) but if the taper be plunged into it, the light is extinguished. Hence it is a combustible body, and not a supporter of combustion. (3.) When 1 measure of oxygen is mixed in a strong *eudiometer* (fig. 47.), with 2 of carbonic oxide, and an electric spark passed through the mixture, a violent explosion occurs, (CO and O being converted into CO_2) and carbonic acid alone is generated. (4.) When a current of this gas is passed over potassium heated in a bulbed tube, the oxygen of the CO is taken up by the potassium, and carbon is dropped in the form of a black deposit (CO and K forming C and KO). (5.) It may be substituted for hydrogen in the same proportion in the oxyhydrogen blow-pipe, and is not liable to explode. Animals when immersed in it, speedily die, just as if they were plunged into water. This gas is formed in many cases of intense

ignition in presence of carbon, as in lime kilns, where it may be distinguished by its delicate blue flame. It is also formed in iron furnaces, and in charcoal stoves, and is very poisonous.

Oxalic Acid. — $CO\ CO_2$ 4·5, *Acid of sorrel, Acid of sugar*, is prepared by heating one part of sugar or potatoe starch with five parts of nitric acid (sp. grav. 1·42) and ten parts of water. By evaporation crystals of oxalic acid are obtained. Sugar consists of equal atoms of carbon, hydrogen, and oxygen; and when heated with nitric acid, the following action occurs.

It may also be obtained by decomposing the salt of sorrel of the shops (binoxalate of potash) by means of sulphuric acid.

Characters.— The crystals of oxalic acid are four-sided oblique prisms. The taste is sour, and the acid reddens litmus paper. When heated to the boiling point of water the crystals lose 21 per cent. of their weight of water. Above this temperature the acid sublimes, or is decomposed. When swallowed, oxalic acid creates great pain in the stomach, and soon proves fatal. The best antidote is lime or chalk, the oxalate of lime being formed, which is innocuous. Oxalic acid is the best test for lime. When a solution of it is dropped into water containing lime a white precipitate is immediately produced, which, dissolved in hydrochloric acid, is again restored by the addition of caustic ammonia. Its *characteristic* property is its power of precipitating lime from its union with sulphuric acid or sulphate of lime. Oxalic acid is very useful in removing stains of ink from linen and cotton. It acts by dissolving the tannate of iron of which the black portion of ink consists. It is to be applied by dissolving a few grains of it in half an ounce of water, and then allowing it to stand in contact with the spot for some time. It answers also for removing spots of ink from tables.

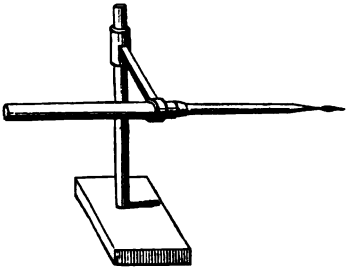
Oxalate of Ammonia, NH_3, C_2O_3 2 HO, 8·875, is prepared by adding carbonate of ammonia to a cold solution of oxalic acid until effervescence ceases. The salt crystallizes in right rhombic prisms, with a bitter taste. This is the form in which oxalic acid is usually employed as a test for lime. When distilled, oxalate of ammonia affords a white powder, *oxamide*, which differs from that salt in having lost the elements of water (HO), and hence its formula is $NH_2\ C_2\ O_2$. This substance is the type or model of the amides, as they are termed,—a series of organic bodies which contain amidogen NH_2 and which when boiled

with caustic alkali give out the smell of ammonia (NH_3). Oxalic acid unites with various bases, forming finely crystalline salts with potash and soda.

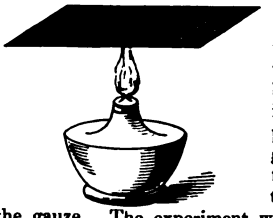
Chlorides of Carbon.— Carbonic oxide unites with chlorine, and gives rise to a gas, chlorocarbonic acid (CO Cl). The most interesting chloride of carbon (C_4 H_4 Cl_2) is that which is formed by mixing chlorine and olefiant gas together, covering up the vessel, and allowing the gases to act upon each other. The gases gradually diminish in bulk, and an oil swims on the surface of the water which has the preceding composition. It is by this action that we are enabled to determine the amount of olefiant gas present in coal or other gases.

Carburetted Hydrogen CH_2. — *Fire damp. Heavy inflammable air. Marsh Gas.* Atm. Wt. 1. Spec. grav. ·555. Wt. of 100 c.i. = 17·211 grs. 1. This gas may be procured by inverting a bottle filled with water in a stagnant pool, supplied with an inverted funnel, stirring the bottom of the pool with a stick, and catching the bubbles which rise in the funnel. 2. It may be also obtained by passing the vapour of alcohol through a red hot porcelain tube; CH_2 and carbonic acid pass over. 3. When coal is heated to redness the principal products of the ignition are tarry matter, and gases containing 70 per cent of carburetted hydrogen, varying according to the heat applied and to the quality of the coal. The experiment may be performed by filling with pounded coal a blacking bottle supplied with a tobacco pipe stem luted on with clay to carry off the gas, or in a tube of Bohemian glass, into which a smaller tube is fitted by means of a cork; the whole being supported by a grasping stand (fig. 71.). On applying the heat of a lamp or chauffer to the coals, the gas comes over, and may be set on fire at the point of the fine tube. The same gas is produced in the ignition of most substances of organic origin. It occurs frequently accumulated in deep coal mines, derived from the decomposition of the coal, and often occasions fatal accidents from the property which it possesses of exploding when mixed with common air, and fired by a light. To prevent such explosions the Davy lamp was invented by Sir H. Davy. Its nature may be understood by taking a piece of fine

71

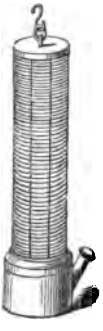


72



wire gauze, and holding it across the flame of a candle or lamp (fig. 72.). It will be observed that the flame does not pass through the gauze, and that if the gauze be held over a gas lamp before ignition, if the gas be allowed to pass out and be lighted above the gauze, when the latter is sufficiently fine it will be found that the flame never descends below the gauze. The experiment with the gauze at the same time enables us to study the structure of flame, which we find to be a hollow cone of light, free from flame in the centre.

73



A Davy lamp simply consists (fig. 73.), of a flame surrounded by wire gauze, which thus prevents the flame from passing to the exterior atmosphere, and igniting the fire damp or carburetted hydrogen. The gauze, which is composed of iron wire is supposed to cool the flame below the point of ignition, and thus to prevent its transference through the meshes. When 1 part of carburetted hydrogen is mixed with from 7 or 8 to 14 parts of common air it is capable of exploding most powerfully. With from three or four times its bulk it does not explode. Hence the danger of omitting to close gas lamps, and of having leaks in the gas pipes. Fortunately coal gas possesses a powerful naphtha odour, which is soon perceptible when it happens to escape. When 2 volumes of oxygen are mixed with 1 volume of this gas they are resolved into 1 of carbonic acid and 2 of vapour of water; $CH_2\ O_2$ becoming $CO_2\ 2\ HO$; a volume of oxygen being equivalent to 2 atoms.

Olefiant Gas (oleum, *oil;* fieri, *to be made*).—*Heavy carburetted hydrogen*, $C_4\ H_4$ 3·5, spec. grav. ·9722, may be obtained by the dry distillation of many organic substances, as fats, &c., or in the dry distillation of coal peat, &c. in close vessels. It is usually prepared by mixing 1 part of alcohol with from 4 to 7 parts of sulphuric acid in a retort or gas bottle, and applying heat. The fluid becomes first brown and then black; the gas comes over in great abundance, but is latterly contaminated with much sulphurous acid (SO_2) and carbonic acid (CO_2).—*Characters.* Colourless, odour ethereal, and burns with a fine white flame, affording much light. Lime water, poured into the jar after combustion, is precipitated, showing the presence of carbonic acid; the products of the burning being CO_2 and HO. It is the most important constituent of gas as a lighting agent. When 3 volumes of oxygen

and 1 of olefiant gas are mixed in a strong glass bottle enveloped in a towel, and the mouth of the bottle is brought to a lighted candle, a violent explosion results, carbonic acid and water being formed (C_2 H_2 and O_6 becoming 2 CO_2 and 2 HO). When 2 measures of chlorine are mixed with 1 of olefiant gas in a large bottle, no action occurs — but if a lighted taper or gold leaf be brought in contact with the gases, combustion takes place with a red light, and lamp-black is copiously deposited, proving the presence of carbon in the gas (C_2); this is a very striking experiment. When exposed to strong pressure and cold, this gas condenses into a clear liquid. This gas does not support combustion, since it is a combustible body. It destroys an animal when plunged into it precisely like water. It is slightly soluble in water. 100 cubic inches weigh 30·15 grains.

Carburets of Hydrogen. — Several carburets of hydrogen have been obtained by the condensation of oil gas, which differ in volatility, and may therefore be separated by different degrees of heat.

Coal Gas. — Which is prepared by heating coals in an iron cylinder and collecting the gas which comes over; consists, when well prepared, of 20 per cent. of olefiant gas, 60 per cent. of carburetted, and 20 of carbonic acid and hydrogen. The spec. grav. of the best coal gas is ·622, but generally as prepared in this country is not above ·500. The best coal for the preparation of gas is cannel coal, termed in Scotland *parrot*, from the crackling sound which it emits when burned. It yields a beautiful light when used as a combustible agent, and may be frequently seen in Glasgow employed for this purpose, in consequence of its comparative abundance in the neighbourhood.

74

Cyanogen (κυανος and γενναω, I produce blue), C_2 N. 3·25, spec. grav. 1·8055.—May be easily prepared by introducing the cyanide of mercury, a salt which crystallizes in square prisms (Hg Cy), into a small retort with a turned up beak, or into a Bohemian test tube fitted with a cork, and bent quill tube (fig. 74.) applying heat and receiving the gas over mercury. *Characters:* it is a transparent colourless gas, possessing a peculiar, disagreeable odour. By a force of 4 atmospheres and cold, it condenses into a fluid, and is solid at —30°. If a light be brought to the beak of the retort while the gas is passing over, it catches fire and burns with a beautiful violet blue flame. It neither supports combustion nor respiration. Water takes up 4 measures of it, and acquires its smell and peculiar taste. It is very soluble in alcohol; it reddens solution of litmus. Potassium, when heated in it, burns with a brilliant

light, and is converted into cyanide of potassium. It unites with other bases and forms salts destitute of water. 100 c.i = 55·99 grs.

Cyanic Acid (Cy O, 4·25). — Obtained by heating yellow prussiate of potash with black oxide of manganese on an iron plate over a fire or lamp, until the whole becomes a black mass: by digesting the mass in water, and evaporating the solution, cyanate of potash is left in white scales (K O Cy O); monobasic acid.

Urea or *Cyanate of Ammonia* (C_2 O_2 N_2 H_4 7·5). — If we take a solution of the preceding salt, mix it with sulphate of ammonia and evaporate, sulphate of potash crystallizes out first, and then 4 sided prisms of urea. It is also obtained from urine by evaporating that fluid down in a bason at the temperature of boiling water, and boiling the residue in spirit. The urea crystallizes out, and may be deprived of colour by means of animal charcoal. By uniting with 2 atoms of water, urea is rapidly changed into 2 atoms of carbonate of ammonia (C_2 O_2 N_2 H_4 2 HO becoming NH_3 CO_2 NH_3 CO_2). It is the odour of the ammonia thus disengaged which is so perceptible in those parts of towns where this fluid is deposited. To preserve it from flying away, the urine should be mixed with sulphuric acid. For every 100 lbs. of cows' urine, 6 lbs. of sulphuric acid should be added to the tank containing it, and for horses' urine, a little more than 1 lb. for every 100 lbs. of fluid. Urea unites with acids and forms a series of salts. The nitrate may be formed by evaporating urine down to the consistence of a syrup and mixing it with an equal measure of nitric acid spec. grav. 1·42. The whole becomes a mass of scaly or needle crystals, consisting of one atom of urea, one of acid, and one of water.

Fulminic Acid (Cy_2 O_2 9·5). — This is the active principle in fulminating mercury employed in percussion caps, and is prepared by mixing 1 part of mercury, 12 of nitric acid, (spec. grav. 1·36) and 11 of alcohol (spec. grav. ·848), and heating in a flask in a water bath; the fulminate of mercury precipitates. It may be separated from the globules of mercury, by dissolving it in hot water, and crystallizing it out of the solution in fine silky needles. It explodes with great violence when the smallest quantity of it is rolled up in paper and struck with a hammer. It is, therefore, a dangerous substance to prepare, and *none but chemists should attempt to make it.* Fulminate of silver, prepared also in a similar manner, is an explosive compound. Percussion caps are filled by rubbing 10 parts of fulminate of mercury cautiously with a wooden pestle on a marble slab, with 30 parts of water; to this paste are added 6 parts of saltpetre, and the mixture introduced in proper proportion into the copper caps. Cyanic acid and fulminic acid present us with examples of *isomerism*, or bodies which have the same composition in 100 parts, but have totally different chemical characters. Cyanuric acid (Cy_3 O_3) is also *isomeric.*

Cyanohydric, Hydrocyanic, or Prussic Acid (HCy 3·375).—The method of preparing this acid is to distil in a retort 15 parts of pounded yellow prussiate of potash (ferrocyanide of potassium) with 9 parts of water and 9 parts of sulphuric acid. The distilled fluid is to be passed into a receiver surrounded with ice. But in this state it is too strong for safety. The hydrous acid is made by distilling 4 parts of prussiate, 18 of water, and 2 of oil of vitriol, into a receiver containing 20 parts of water. The process is carried on with the careful application of heat until the fluid in the receiver amounts to 38 parts.

Characters. — It is a colourless acid, having a powerful odour similar to that of peach blossoms. Taste sharp, at first cooling, then burning. It scarcely reddens litmus paper. When very strong it speedily decomposes, depositing a brown matter, which may be prevented by the addition of a drop or two of sulphuric acid, or of a small portion of alcohol. It forms, with nitrate of silver, a curdy precipitate, which disappears in nitric acid by boiling, and the smell of prussic acid is evolved. When freshly prepared a few drops of this acid speedily destroy animal life. It should not therefore be placed in the hands of inexperienced persons. Even during its preparation the fumes sometimes produce faintness. The best antidote in this case is to smell the vapour of strong caustic ammonia, which neutralizes the acid, and restores consciousness. The best *tests* for this acid are 1st, its smell; 2d, its action with nitrate of silver; 3d, when the fluid containing it is poured into a solution of a mixture of sulphates of peroxide and protoxide of iron (a decomposing specimen of copperas answers well). the fluid neutralized with ammonia, and then a few drops of chlorohydric acid added, a fine precipitate of Prussian blue falls down, which is characteristic. But the most beautiful test is the following (Liebig). 4. Pour into a test tube half a drachm of the suspected fluid, an equal bulk of sulphohydret of ammonia, and 4 grains of flowers of sulphur. Boil over a lamp until the smell of SH disappears. Filter, and add a drop of the liquid to a solution of pernitrate or perchloride of iron. *A blood red* sulphocyanide of iron falls.

Cyanide of Potassium (KCy 8·25). — A salt crystallizing in white cubes; may be prepared by calcining the yellow prussiate of potash in a close vessel, digesting the residue in cold water, filtering, evaporating to dryness, and boiling the white residue with alcohol, Sp. grav. ·896. The cyanide separates on cooling. It is sometimes used for photographic purposes, and then its purity is of less consequence. When 8 parts of dried yellow prussiate are fused in a covered clay crucible, with 3 parts of dry carbonate of potash, the mixture becomes black, the portion on the surface being a clear fluid. It is to be poured off from the

dark matter at the bottom into a porcelain bason or upon a clean slab. It contains some cyanate and carbonate of potash.

Ferrocyanide of Potassium ($Cy_6 Fe_2 K_4$, or $Cy_3 Fe K_2$). *Iron Cyanide of Potash*, or *Yellow Prussiate of Potash*.—This salt crystallizes in truncated octahedrons, and is made by heating carbonate of potash in an iron pot, and stirring into the fused mass animal matters, such as hoofs, horns, woollen rags, or any substances containing nitrogen. The salt is then removed from the pot, and digested in water. This liquor when evaporated yields the yellow prussiate in large beautiful yellow crystals. It can also be formed by passing the nitrogen of the air over potash and charcoal intensely heated. It is soluble in water, and affords the best test for peroxide of iron, and oxide of copper, which we possess. If we add a drop of it to a weak solution of perchloride of iron, Prussian blue immediately falls, and when mixed in a similar manner with a solution of copper, a brownish red precipitate makes its appearance.

Prussian Blue ($Fe\ 7\ Cy_9$) is the fine blue colour used for dyeing woollen dresses, and is made as above described. It possesses a fine soft dark blue colour, and is often used under the name of *blue* by washerwomen to hide the yellow colour of linen. *Blue ink* is prepared by triturating Paris Prussian blue with $\frac{1}{6}$ of its weight of oxalic acid in water. *Ferridcyanide of potassium*, or *Red Prussiate of Potash*, $Cy_6 Fe_2 K_3$, is a fine red prismatic salt, and is obtained by exposing the yellow prussiate in powder to the action of an atmosphere of chlorine. This gas removes one atom of potassium, and forms chloride of potassium ($Cy_6 Fe_2 K_4$ and Cl becoming $Cy_6 Fe_2 K_3$ and K Cl). This is the best test which we possess for the protoxide of iron, thus forming a fine Prussian blue, having the composition above described. The manufacture of the preceding substances is one of great importance in the arts, as from them proceed some of the finest colours in the whole range of chemistry. It is believed that by heating animal matter and potash together, a cyanide of potassium is formed (K Cy), while iron is removed from the pots, and when the contents of the pots are digested in water the cyanide dissolves up the iron, and forms the yellow prussiate. Similar compounds are formed by means of cobalt and cyanogen. The iron is believed to unite with the cyanogen, in the form of what is termed an *organic radical* ($Cy_3 Fe$), and this again with potassium. In the red prussiate this radical is supposed to be doubled ($Cy_6 Fe_2$).

Sulphocyanide of Potassium (K Cy S_2) is obtained by heating 1 part of flowers of sulphur with 2 parts of powdered yellow prussiate previously dried at 212°. Dissolve the fused mass in water, and add a solution of carbonate of potash as long as a precipitate of iron falls; boil the mixture, filter and evaporate. Long prisms and needles separate, which are poisonous. This salt

affords a beautiful test for peroxide of iron. A quantity of iron present in a dilute solution is made apparent on the addition of a few drops of a solution of this salt in the form of a fine blood red colour.

Platinocyanide of Potassium ($Pt\,Cy_2\,K$), in fine bluish yellow needles, is formed by fusing in a porcelain bason over a lamp 2 parts of dry yellow prussiate with 1 part of spongy platinum, dissolving the fused mass in water, filtering and crystallizing. If Cl be passed through a solution of this salt, a brilliant golden salt is formed, containing half the amount of potassium. Palladium, iridium, chromium, and manganese form similar salt radicals.

Cyanogen unites with chlorine in two proportions, forming a gaseous and solid chloride; it also unites with barium. *Mellon*, $C_6\,N_4$, yellow powder, an organic base obtained by heating in a retort, to redness sulphocyanogen; it decomposes into CS_2, sulphur and mellon; with potassium forms mellonide of K, from which hydromellonic acid may be obtained by HCl. When mellon is boiled with NO_5 octahedral crystals appear of *cyanilic acid*, having the same composition as cyanuric acid. *Melam*, $C_{12}\,N_{11}\,H_9$, white powder, obtained by heating sulphocyanide of ammonium to the point of fusion; the products are NH_3, SH, CS_2, and melam. *Melamine*, $C_6\,N_6\,H_6$, yellow rhombic octahedrons, obtained by boiling crude melam, after removing K Cl, with weak caustic potash. *Ammeline*, $C_6\,N_5\,H_5\,O_2$, silky needles insoluble in alcohol and ether, obtained from the caustic solution after the preparation of the preceding body; it exists in the liquid, and is precipitated by acetic acid. This is treated with NO_5, converted into nitrate of ammeline, 4-sided square prisms, and is precipitated pure by carbonate of ammonia. *Ammelide*, $C_{12}\,N_9\,H_9\,O_6$, white powder, insoluble in water, alcohol, and ether, but soluble in acids and alkalies: obtained by treating melam, melamine, or ammeline, by solution in SO_3, mixing with alcohol, and washing the precipitate with water. *Sulphomellone*, $C_6\,N_4\,H_2\,S_4$? *Hydrosulphomellonic acid*, obtained by treating sulphocyanogen with KS, HS, and adding acetic acid. *Uric acid*, $C_{10}\,N_4\,H_4\,O_6$, or $_2Cy+4CO$ (Urile)+ Urea, brilliant scales and needles; contained abundantly in the urine of fowls and boa constrictors, and frequently in guano, if not too much decomposed. The acid may be obtained by boiling the dung of the boa with a dilute solution of caustic potash till NH_3 ceases to be expelled and filtering. On the addition of HCl to the filtered liquor uric acid precipitates, and is to be well washed. It unites with bases forming with soda, urate of soda: often found in the joints of gouty persons, and known as chalk stones. *Uric acid* is the most common constituent of calculi; it may be distinguished by its dissolving in NO_5, and giving a purple colour when carefully evaporated in a white basin, or by adding fuming acid, and then NH_3. *Allantoin*, $C_4\,H_3\,N_2\,O_3$, colourless rhombic prisms, obtained by boiling 1 uric acid, 20 water; brown oxide of lead is to be added as long as its colour changes. The allantoin is obtained by filtration and evaporation; this substance occurs in the allantoic fluid of the cow. *Alloxan*, $C_8\,N_2\,H_4\,O_{10}$, colourless right prisms, efflorescent, obtained by dissolving uric acid in NO_5 (1·45), and allowing the mother liquid to drain off. *Alloxanic acid*, $C_8\,N_2\,H_2\,O_2\,2HO$, radiated needles, obtained by treating alloxan with alkalies. *Leucoturic acid*, $C_6\,N_2\,H_3\,O_6$, white powder, obtained by evaporating a strong solution of alloxanic acid at a certain temperature. *Dialuan* is found in the liquid which deposites the preceding acid. *Mesoxalic acid*, formed by heating alloxanate of barytes to the boiling point. *Mycomelinic acid*, prepared by heating alloxan with an excess of ammonia. *Parabanic acid*, formed by heating alloxan or uric acid with NO_5, and evaporating. *Oxaluric acid*, obtained by heating parabanic acid with NH_3; the acid may be separated by SO_3. *Thionuric acid*, formed by causing sulphite of NH_3 to act on alloxan. *Uramile* is prepared by treating thionurate of NH_3 with HCl. *Uramilic acid*, prepared from the preceding by treating with SO_3. *Alloxantine*, $C_8\,N_2\,H_3\,O_{10}$, oblique 4-sided prisms, formed by adding dilute NO_5 to uric acid, and evaporating down one third; or by

passing SH through alloxan. *Dialuric acid*, obtained by passing SH through a boiling solution of alloxantine and adding NH_3; dialurate of NH_3 separates in silky crystals. *Alliturie acid*, prepared by boiling alloxantin with $HClNO_5$. *Diliturie acid*, obtained from the mother liquor of the preceding body by SH. *Murexide*, $C_{12}N_5H_6O_8$, purpurate of NH_3 of Prout, 4-sided prisms, with a beautiful green metallic lustre, obtained by dissolving uric acid in dilute NO_5, and evaporating till it acquires a flesh colour; it is treated with NH_3 in slight excess; it is then diluted with half its weight of boiling water, and allowed to cool. It may also be obtained by mixing 7 grs. alloxan, 5 alloxantine, dissolved in 240 grs. water, with 80 grs. of a cold strong solution of carbonate of ammonia. *Murexan*, $C_6N_3H_4O_5$, purpuric acid of Prout, silky scales, insoluble in water; prepared by dissolving murexide in caustic potash, and adding SO_3 in excess. *Xanthic oxide*, $C_5N_2H_2O_2$, a rare calculus, dissolves in NO_5, leaving a yellow residue, which is not redissolved by NH_3; somewhat soluble in water. *Cystic oxide*, an organic base, $C_6NH_5O_4S_2$, yellowish white crystals; a rare calculus, soluble in alkalies, decomposed by heat, with evolution of SO_2, and NH_3. *Guanine*, $C_{10}H_5N_5O_2$, white crystalline powder, extracted from guano by HCl, and precipitated by alkalies; it is a base uniting with acids and forming salts. *Hyperuric acid* ($C_{10}N_4H_3O_7$ 2 H C) by oxidating guanine.

Boron.

B, 1·25, a brown powder obtained by heating, in a tube, calcined boracic acid with potassium (BO_3 and 3K become B and 3KO); the oxygen is removed by the potassium and forms caustic potash, while the boron is set free; the potash may be washed out with water, and the boron remains. *Boracic acid*, BO_3, 4·25, white 6-sided pearly scales, which are obtained in an impure state in the hot springs of Tuscany. It may be purified by uniting it with soda, and decomposing the borax thus formed by sulphuric acid. It dissolves in sulphuric acid, water, and alcohol. Its presence can be easily distinguished when it is in solution in alcohol. If we place the solution in a bason, and set fire to it, the edges of the flame are tinged with a green colour. *Test in combination.*—Pour on it SO_3, add alcohol, and burn it; if this acid is present the flame will be tinged green. *Borax*, NaO $2BO_3$ 10HO 23·75. This salt may be prepared as already described. It occurs also native in Thibet, under the name of tincal. It crystallizes in 6-sided prisms, and converts vegetable blues to green; a curious anomaly in the history of an acid salt. This salt is employed in certain diseases of the mouth in children, and is then given mixed with honey. It is used also as a flux for metals, and for detecting substances before the blowpipe (p. 17.). It enters as a constituent into the glazes employed for the finer kinds of porcelain.

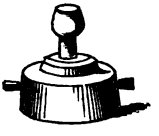
Silicon. Si. 1.

This substance is the basis of flint, quartz, sand, &c., is a brown powder resembling boron ,and may be procured by an analogous process.

Silica or *Silicic Acid* (Si O 2).—This is one of the most common constituents of the globe, and is well known under various names. 1. Quartz, when pure, is milk-white, and is then known under the title of chucky stones; when *violet* coloured it is called amethyst; when *red*, rose quartz; *cairngorum* when yellowish; when crystallized and transparent in 6 sided prisms terminated by 6 sided pyramids, it is called rock crystal. In Brazil, these crystals occur of such large size, that the eyes of spectacles are usually made from them; their advantage over glass

depends upon their more regular surface, glass having more or less of a wavy surface. Rock crystal may be distinguished by its crystalline form, and from calcareous spar by its scratching glass, and not yielding under the nail. 2. Chalcedony is a form of silica, apparently deposited from water in which it has probably been dissolved when united with an alkali. *Agate* is a form of chalcedony, marked, by consisting of bands of different colours. *Bloodstone* is a variety distinguished by having blood-red veins. *Carnelian* is another variety brought from India. 3. Flint occurs in isolated masses in chalk, and is supposed to be of organic origin. Silica, as it occurs in all these forms is usually contaminated with certain impurities, usually iron. These may be removed by pounding the native mineral in a diamond mortar (figs. 75, 76.). This consists of a steel box fitted with a piston.

75



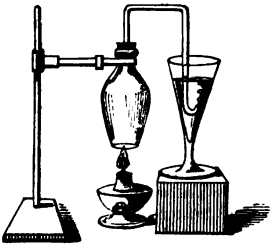
76

Fragments of the substance are placed in it. The piston is introduced and struck with repeated gentle blows of a hammer. The powder is then placed in quantities of about a grain at a time in an agate mortar (fig. 77.), and reduced carefully to a very fine powder. In absence of these mortars, the mineral may be pounded in an iron or steel mortar. It is then fused for 20 minutes in a platinum crucible with 3 times its weight of carbonate of soda previously deprived of its water by heat, (anhydrous carbonate of soda). The fused mass is dissolved out with hydrochloric acid and water, and placed in a porcelain bason. The solution is evaporated and heated until the acid ceases to be detected by the smell, and is again sprinkled on it, and the whole left in this cold state for an hour. Water is then added, heated, and the whole filtered. The silica remains on the filter. It is to be washed by repeated additions of hot water until a drop of the liquid passing through gives no precipitate with nitrate of silver. The funnel with the filter is then placed in a stove to dry, and the last traces of water removed by heating the silica in a covered crucible to redness. When thus prepared, it is a beautiful white powder, feeling gritty between the teeth, fusing into a colourless glass bead with carbonate of soda before the blowpipe and dissolving completely when boiled in a solution of carbonate of soda. Silica is a very

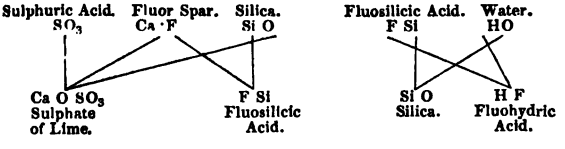
77

important substance both in nature and art; it forms the chief ingredient of soils; in sandy soils the amount of silica varies from 70 to 90 per cent.; in clay soils it is less than 70; in granite there is present 87 per cent. of silica; in mica slate, 68 per cent.; in clay slate 56; and in graywacke 74 per cent. *Gun flints* are made from masses of flints, and chipped into the proper forms by a hammer. *Millstone* or *Burr stone*, occurring at Paris and at Holken, in England, consists principally of quarts, to which it owes its hardness and utility for grinding. *Sandstone* employed as a grindstone, also contains much silica. *Glass* consists of various kinds. *Flint glass*, of which glasses and tumblers are made, is formed by fusing oxide of lead, sand, and carbonate of potash together. *Window glass* is made of sand, lime, soda, and alumina. *Bottle glass* of coarse river sand, lime, and some potash. *Crown glass* of fine sand, lime, and potash. If we fuse pounded glass with 8 or 9 times its weight of carbonate of soda, it becomes soluble in water. *Fuck's soluble glass* is made by heating 15 parts pure sand, 10 parts carbonate of potash, and 1 of charcoal. This, when dissolved in 4 or 5 parts of boiling water, and evaporated to the specific gravity 1·24 deposits on surfaces on which it is placed by spontaneous evaporation a glassy glaze, which has been used as a preservative against fire.

78



Fluosilicic Acid (Si F) is formed by mixing finely powdered glass or sand, fluor spar and sulphuric acid in a flask supplied with a bent tube (fig. 78.), or in a retort. On the application of heat fluosilicic acid comes over, which smokes; or if it be passed through water, the silica is deposited in a beautifully gelatinous form. The action is as follows: —



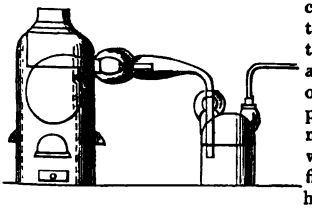
The first scheme exhibits the production of the gas, the second the deposition of the silica in water. In *etching* on glass, this gas is formed by pouring sulphuric acid (SO_3 HO) on fluor spar Ca Fl. Sulphate of lime is formed (Ca O SO_3) and fluohydric

acid is set free (H F). This gas comes in contact with the silica of the glass, and by forming fluosilicic acid (Si F) the glass is corroded. If the glass be previously covered with melted wax, and a figure be drawn on it with a sharp pointed instrument, any design may be etched. By means of this property of hydrofluoric acid we are enabled to detect the presence of fluor spar.

PHOSPHORUS. P. 4. (*Brandt*, 1669).

Phosphorus is prepared by calcining bones, pounding them and passing them through a sieve; the powder is made into a paste with water, and placed in a wooden vessel. To 10 lbs. of bones are added 6 lbs. of sulphuric acid, and the mixture allowed to stand for twenty-four hours. The vessel is filled up with water, the liquor drawn off, and replaced by water three times; these united washings are evaporated to dryness, the residue mixed with one-fourth of charcoal, and heated in a retort for thirty hours, at a high temperature. The phosphoric acid (PO_5) is deprived of its oxygen by the carbon, and phosphorus distils over, and must be allowed to drop into water as represented in the figure 79. After a quantity has passed over, it is usual to melt the phosphorus under hot water, and suck it into tubes; thence the substance is sold in the form of sticks. When pure it is solid, light amber-coloured, translucent, easily cut with a knife or bent with the fingers, especially in hot weather; melts at 108°, boils at 554°. Sp. grav. 1·77. Of vapour 4·355; poisonous.

79



Phosphorus and Oxygen, Phosphoric Lamp. — When a portion of it is dissolved in oil in a bottle, if the bottle be left half empty the phosphorus shines in the dark; labourers use this to distinguish the hour on their watches during the night. This phenomenon depends on the great affinity which phosphorus has for oxygen; the light which it emits is simply its slow combustion or union with oxygen. *Subaqueous Light.* — This affinity is well seen in a pretty experiment, which, when carefully made, is not attended with risk, and has been already described under chloric acid. *Lucifer matches* depend usually for their power of exploding or taking fire, to the rapid union of phosphorus with the oxygen of the chlorate of potash. They may be made as follows; — dissolve 7 parts of gum-arabic, and 2 of glue or isinglass, in water of 140°, so as to make a thick mixture; add

4 parts of phosphorus, and sufficient red lead or indigo to give a colour. Stir till the phosphorus disappears, mix then 2 parts of chlorate of potash previously pounded and moistened with mucilage. Matches whose points have previously been immersed in melted sulphur, are then dipped in the mixture; in making this experiment, very little hazard will be experienced, if the quantities used do not exceed a few grains.

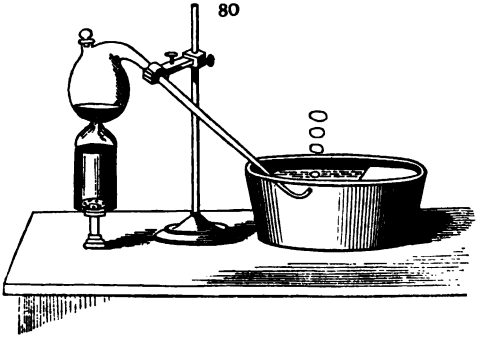
Phosphorescence is usually ascribed to the union of oxygen with phosphorus; thus, when fish are exposed to the air and begin to smell, the phosphoric acid which they contain being deprived of its oxygen by the carbon of the animal (to form carbonic acid (2 PO_5 and 5 C becoming 5 CO_2 and 2 P), the phosphorus immediately begins to unite with oxygen, and forms the well known lambent flame. It is supposed that the beautiful luminous appearance in the sea, more particularly between the tropics, but also visible in summer in the British seas, is due to a similar phenomenon, the decay of the small jelly fish or blubber, so abundant in the ocean. Fluor spar when heated, phosphoresces or becomes luminous in the dark, owing to what cause, unless it be to the presence of phosphoric acid, is still doubtful.

If we place some phosphorus in a test glass containing hot water, and then pass from the gasholder, by means of a bent tube, a stream of oxygen through the fused mass, a brilliant combustion occurs, occasioned by the combination of the phosphorus and oxygen. It is a mixture of phosphorus and oxide of phosphorus. *Hypophosphorous acid* (PO 5) is obtained by boiling barytes with phosphorus, and decomposing the hypophosphite of barytes by means of sulphuric acid. *Phosphorous acid* (PO_3 7) is made by the imperfect combustion of phosphorus, or by dissolving phosphorus in nitric acid. When the solution is concentrated as much as possible, the acid still retains 3 atoms of water, its composition being 3 HO PO_3; when heated strongly, it passes into *Phosphoric acid*, PO_5 9; or *Bone acid*, from its constituting a part of the earth of bones. It may be formed by burning phosphorus in oxygen gas or common air, and dissolving the white flocks formed in water; the water in this case is found to redden litmus paper. The best method of preparing phosphoric acid, however, is to calcine bones and mix them in powder with from 15 to 20 times their weight of water in a porcelain or lead vessel, and then add 9½ parts of sulphuric acid. After standing for a day, as much more water is to be added, and the mixture allowed to remain at rest for a similar period, being frequently agitated. The whole is then filtered through calico; the filtered fluid is evaporated to a syrup, and sulphuric acid added as long as sulphate of lime is precipitated. The whole forms into a mass, to which water is to be added; it is then thrown on a filter, and the liquid evaporated to dryness. To obtain the acid pure, the re-

sidue is digested in alcohol; a salt of magnesia precipitates; when pure the acid is solid, resembling ice, and hence it is called *glacial acid* ($3\,HO\,PO_5$). If to this acid dissolved in water we add a solution of nitrate of silver, a yellow precipitate falls of trisphosphate of silver ($3\,AgO\,PO_5$), where the silver displaces the water. If this acid be saturated with soda, we obtain phosphate of soda, used as a mild medicine ($HO2\,NaO\,PO_5\,24\,HO$), known as common phosphate of soda, and yielding the yellow precipitate with silver; if this salt be heated it becomes $2\,NaO\,PO_5$, and when nitrate of silver is added to it, a white precipitate falls ($2\,AgO\,PO_5$) of *pyrophosphate* or *diphosphate* of silver, while the yellow precipitate is the *trisphosphate* or common phosphate. It is obvious that by the heat the atom of water has been removed, which must have acted the part of a base. Both of these forms of acid combine always with the same number of atoms of base. Protophosphoric acid is capable of uniting with only one atom of base. This form is obtained by heating the biphosphate of the shops, $2\,HO\,NaO\,PO_5$; it then becomes $NaO\,PO_5$ or protophosphate of soda; when it is added to a solution of silver, it yields protophosphate of silver ($AgO\,PO_5$), a monobasic phosphate of silver as it has been termed. *Graham.* Phosphoric acid is a most important substance in animals and plants: without it neither the one nor the other could be formed. It appears to exist in almost all rocks, a good evidence of its presence being the growth of lichens on their surface. It is principally from the presence of this acid in bones, that they are so extensively used as a manure, and that the excretions of animals are employed for the same purpose.

Phosphuretted Hydrogen (PH_3 4·375), a colourless transparent gas, made by boiling thin slices of phosphorus in a retort with turned-up beak in contact with caustic potash or soda (fig. 80 or 78.).

80



The phosphorus takes hydrogen from the water; a portion of it therefore goes to form hypophosphite of potash, while the hydrogen unites with another portion, and the gas passes over. When allowed to pass under the surface of water, the bubbles catch fire as they come to the surface, and form beautiful round rings of smoke, which gradually expand as they ascend; this smoke is phosphoric acid. If a tumbler be filled with this gas, and carefully inverted with a plate of glass over its mouth, the remarkable phenomenon is exhibited, when the glass is removed, of an empty tumbler bursting into flame. If the gas is allowed to stand over water it loses its self-inflammable power, which is due to the presence of a volatile fluid existing in the gas, which may be condensed by ice cold water (PH_3). Sp. grav. of gas 1·185.

The curious phenomenon of Will-o'-the-wisp, only observed in marshy countries, where a flame or light is seen at night to move over the surface of the ground, is due to the presence of this self-inflammable phosphuretted hydrogen. Besides the gaseous and liquid compounds, there is also a solid combination of phosphorus and hydrogen, prepared by passing the common gas above described into hydrochloric acid: a solid phosphuret is formed (P_3H).

Sulphur, or Brimstone. S. 2.

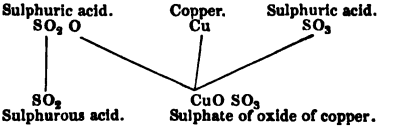
Sulphur has been known to mankind from the earliest ages in a free state, and also united with iron, copper, &c., under the names of iron and copper pyrites, or firestone. The great supply in Europe is from the island of Sicily, where it is quarried from large deposits, situated in a blue clay formation. When taken out of the earth it is melted in earthen pots, and heated so as to cause it to distil over into water. In this condition it is brought to England. It possesses a crystalline structure. To make *roll sulphur*, this crude sulphur is melted; the impure matter allowed to subside, and the melted sulphur poured into wooden moulds. *Flowers of sulphur* is the usual form in which sulphur is used in medicine. It is a fine yellow powder, and is made by heating sulphur to its boiling point; it sublimes in a large apartment, and on cooling is deposited in the form of a fine powder. For external application in skin diseases, this powder is rubbed up in a mortar with some fat or lard, and forms sulphur ointment. It is particularly used for the cure of itch; a disease produced by the itch insect, which burrows in the skin, and is encouraged by the presence of filth. Any poison, such as a solution of corrosive sublimate, will destroy the insect.

Characters. — When crystallized, sulphur is in long needle-shaped crystals of an octahedral form. When melted and cooled it as-

sumes the form of doubly oblique 4-sided prisms. These two crystalline forms are incompatible with each other; and hence, sulphur is said to be a *dimorphous* body (*δίς* and *μορφη*, two shapes). Sulphur is a hard brittle body possessing a yellow colour with a shade of green, and does not conduct electricity. When rubbed with a woollen cloth it becomes electrical, or capable of conducting light bodies towards it; melts at 230°, boils at 860°. When melted and poured into water it remains for some time soft, and is used in this condition to take off impressions, as of medals and coins, and thus to prepare moulds for electrotype, when its surface has been rubbed over with plumbago. Sp. Grav. 2·087.

Sulphur is used to prepare sulphur matches (*spunks*, in Scotland). These are made by splitting wood into the requisite sizes, by means of a knife, tying them in a bundle, and dipping their ends in melted sulphur. A good workman, it is said, will make 4000 of them in an hour. When sulphur is adulterated with sulphate of lime, it may be detected by heating the sulphur on a porcelain spoon, or platinum spatula; the sulphur burns away with a blue flame, and leaves the adulteration.

Sulphur and Oxygen. — Sulphur unites with oxygen in various proportions. When we burn sulphur in the air it gives out white fumes, and a blue flame. The odour is peculiarly suffocating, and well known; the fumes are *sulphurous acid*, SO_2, 4·, or *volatile spirit of sulphur* of the old chemists. This acid may be procured in a purer form by boiling sulphuric acid with copper turnings or clippings, or mercury. The action is as follows: —



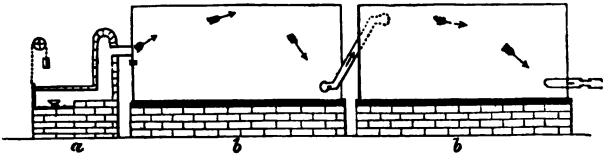
It may be collected by displacement, as with carbonic acid, or over mercury, but not over water, as it is very soluble in that fluid; sp. grav. 2·222·, or 370 times lighter than water. It can be condensed into a liquid by pressure, and at —5° is a solid: by passing a current of the gas through water the properties of it may be examined.

The solution is colourless, possesses the smell of burning sulphur, reddens vegetable blues. It combines with bases, forming sulphites, which are decomposed by stronger acid, the odour of the gas being evolved. The gas is an important agent in bleaching woollens: blankets, or other woollen substances to be bleached, are suspended in an air-tight sulphur house, and freely exposed to the action of the gas.

Sulphuric Acid (SO_3 5), *Oil of Vitriol.* — This common acid is

made by burning sulphur in a furnace, *a*, so as to convert it into sulphurous acid. In the same furnace a pot is placed containing nitrate of soda, upon which sulphuric acid is poured; nitric acid escapes, and acting on the sulphurous acid, is absorbed by water contained in large chambers of lead. The figure represents,

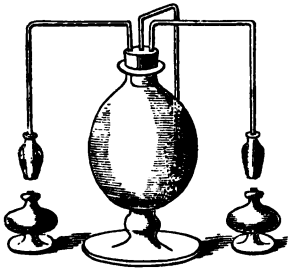
81



a, the sulphur and nitre furnace; the sulphur being scattered on the floor of the furnace, and the soda nitre in the cup; the fumes pass in the direction of the arrows into the leaden chambers, *b b*, which communicate by means of a tube extending transversely. At the further end of the two chambers there is an exit tube for the surplus vapours, which either escape into the chimney, or are condensed by moist columns of coke.

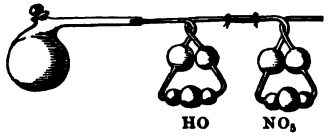
Sulphuric acid may be formed by connecting, by means of bent tubes, three small flasks with a large vessel or flask; into two of the flasks copper turnings are introduced, and into the third water, for the purpose of generating steam. If we pour sulphuric acid upon the copper in one of the flasks, and apply heat, sulphurous acid is given out (fig. 82.), and enters the central vessel by the bent tube. Upon the copper in the other flask nitric acid is poured, and deutoxide of nitrogen evolved; as it mixes with the air of the flask it unites with oxygen and forms (NO_4) hyponitric acid; these, in contact with water, cover the sides of the flask with crystals. As soon as they are formed, if steam be admitted the crystals are decomposed, and sulphuric acid makes its appearance, which can be proved by its giving a white precipitate with chloride of barium, insoluble in nitric acid.

82



Another and more correct method of studying the production of sulphuric acid is, to pass sulphurous acid from copper and sul-

83



phuric acid placed in a retort, through a bulbed tube containing nitric acid (fig. 83.). Another bulbed tube containing a small portion of water may be used for the purpose of washing the gas. The whole of the nitric acid is converted into sulphuric acid, and nothing but NO_2 passes over, $NO_2\ O_3$ and $3SO_3$, becoming $3SO_3$ and NO_2. This is the ultimate action.

Characters.— Sulphuric acid prepared by any of the preceding methods is an oily looking body, and can never be obtained stronger than in union with one atom of water ($HOSO_3$ 6·125 protohydrate). It has no colour when pure, but sometimes acquires a dark shade by straws falling into it. Boiling point 620°. Freezing point 29°. It unites with bases and forms *sulphates*. It is used in bleaching, in the conversion of common salt into soda, and also to dissolve silver out from gold, when these two metals are mixed together, as is the case with the Chinese silver. It converts starch into sugar, and glue into glue sugar. *Dihydrate of sulphuric acid*, or Nordhausen acid, is formed, in Germany, by distilling sulphate of iron or common copperas. It consists of $HO\ 2\ SO_3$, and is always free from nitric acid, which is often present in the common oil of vitrol, from the nature of the process. It answers well in this pure form for the solution of indigo, and for laboratory experiments. Sp. grav. of $H\ O\ SO_3$, 1·842.

Solid Sulphuric Acid (SO_3) may be obtained by passing oxygen and sulphurous acid into a bulbed tube heated, containing spongy platinum. It presents the appearance of thin white silky filaments which are tough and difficult to cut, and produce a hissing sound when thrown into water. Specific grav. 1·97. Melts at 77°.

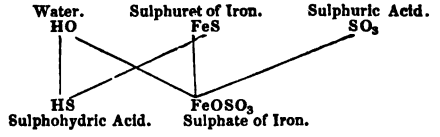
Dilute Sulphuric Acid is used in medecine. It is made by adding 13 parts of water to 1 of common oil of vitrol ($HOSO_3$). The dose amounts to from 10 to 40 drops as a strengthener of the stomach, and should be dropped into a wine-glassful of water, and sucked with a straw to prevent its action on the teeth. When taken in large quantities it acts as a poison. The best antidote is chalk diffused in water, or carbonate of soda. Sulphuric acid unites with bases, and forms salts which differ in composition according to the nature of the base. Iron, manganese, nickel, magnesia, and zinc, form sulphates which are constituted on the same model; the sulphate of iron being $FeO\ SO_3\ 7HO$. All these salts are capable of uniting with sulphate of potash, which then replaces an atom of water, the potash sulphate of iron consisting of $FeOSO_3$ $KOSO_3$, $6HO$.

Chlorosulphuric Acid is formed by the action of the sun's light upon a mixture of dry sulphurous acid and chlorine. It consists of SO_2 Cl = 8·5. *Nitrosulphuric Acid*, (NO_2 SO_2 7·75), is prepared by mixing a saturated solution of sulphite of ammonia with 5 times its bulk of caustic ammonia, and passing through the mixture deutoxide of nitrogen (NO_2) for some hours: crystals are formed, which must be washed with cold caustic ammonia.

Sulphurous Acid as a Radical.— This acid may be viewed as the radical or base of all the oxygen sulphur acids. 1. When sulphite of soda is treated with sulphur, the soda is dissolved, and *hyposulphurous acid* or *sulphuretted sulphurous acid* (SO_2 S) is formed (NaO SO_2 and S becoming NaOSO_2 S). 2. When the same acid is passed through water with Mn O_2 suspended in it, oxygen is taken up (2 Mn O_2+3 SO_2 becoming Mn OS O_2 O_5 and Mn O SO_3) and *hyposulphuric acid* or sulphate of sulphurous acid (SO_2 SO_3) is formed. 3. When bisulphite of potash is heated with flowers of sulphur, *sulphuretted hyposulphuric acid* is formed (SO_2 SO_3 S or S_3 O_5). 4. When a hyposulphite is treated with iodine, *bisulphuretted hyposulphuric* acid appears (SO_2 SO_3 S_2) in consequence of 2 (Na O S_2 O_2) and I becoming Na I + Na O S_4 O_5). 5. When SO_2 in water acts on chloride of sulphur, *tersulphuretted hyposulphuric acid appears* (SO_2 SO_3 S_3). All these acids unite with one atom of base.

Chloride of Sulphur (S_2 Cl 8·5).—A brownish fluid, with a smell of sea-weed, formed by passing chlorine through flowers of sulphur and distilling. (Thomson, 1803.)

Sulphohydric Acid; Sulphuretted Hydrogen (SH 2·125). — A colourless transparent gas, with the smell of decaying eggs, does not support combustion or life, burns with a pale blue flame, very soluble in water, 1 vol. of water absorbing 2½ of gas; reddens litmus; a strong narcotic poison. Sp. grav. 1·1805. *Preparation.* Introduce into a retort or gas bottle a quantity of sulphuret of iron (FeS), prepared by heating a rod of iron red hot, and bringing in contact with it a roll of sulphur, and allowing the sulphuret of iron formed to drop into water; pour over it a small portion of water, and then add an equal quantity of sulphuric acid. Sulphuretted hydrogen gas is copiously evolved according to the following scheme.



When a stoppered bottle is filled with this gas (which may be effected by displacement), and a few drops of strong nitric acid poured in, and the mouth of the bottle immediately stopped with the thumb, armed with a glove, an explosion occurs. Sulphur is deposited and light evolved. Tin when introduced into the gas and heated, combines with the sulphur, and evolves heat. Sulphuretted hydrogen when brought in contact with blood darkens its colour, it is supposed by acting on the iron which

the blood globules contain. Sulphuretted hydrogen is a most important re-agent in chemistry. When a current of it is passed through solutions of metals it precipitates, some of them black, others brown, others yellow, &c. (See Tables.) One of the most convenient forms in which it can be used is in union with ammonia, the *bisulphohydret of ammonia*. This re-agent is prepared by passing sulphuretted hydrogen through caustic ammonia, until the latter no longer gives a flocky precipitate with a salt of magnesia. Sulphuretted hydrogen occurs in solution in mineral waters. These waters, such as Moffat, Strathpeffer, Harrowgate, are distinguished by their possessing the odour and taste of putrid eggs, and by their affording a black precipitate with salts of copper, silver, &c. They can be easily imitated by passing a stream of the gas through water, and allowing it to stand in the air till the excess of the gas has passed away. Too large a dose might prove injurious. This gas, from its poisonous qualities when inspired, has been recommended for the purpose of destroying rats or mice. All that is necessary is to introduce the beak of a retort into a rat-hole during the time that the evolution of sulphuretted hydrogen is taking place from the interior of the retort.

Sulphur unites with carbon (CS_2): when four parts of iron pyrites (FeS_2) are distilled with one part of charcoal, a limpid fluid passes over. It also combines with phosphorus, and forms a compound which is apt to explode when heated above 160°. Its preparation is therefore attended with risk.

Selenium Se. 5. (*Berzelius*, 1817.)

From σελήνη, *the moon*; occurs in nature united with lead and silver; a deep brown-coloured substance with a shining lustre, but possessing no appearance of a metal; capable of crystallising in cubes. Sp. grav. 4·3, nearly allied to sulphur. When heated it emits the odour of horse-radish. It unites in two proportions with oxygen, forming *selenious acid* (SeO_2) and *selenic acid* (SeO_3); bodies which are isomorphous with the corresponding acids of sulphur. The former is prepared by burning the metal in oxygen, and the latter by detonating selenium with saltpetre. Sp. grav. of fused Se. 4·3; of granular Se., 4·8.

Tests. — When SeO_3 is boiled with HCl, the odour of Cl is evolved: solution not precipitated by SH. White precipitate with Ba Cl insoluble in NO_5: SeO_2 reduced to metallic state by solution of SO_2. Selenium fuses at 212°.

Tellurium Te. 8. (Tellus, *the earth*.)

This metal occurs in nature in the form of native tellurium, in which ore it was discovered by Müller of Reichenstein, in 1782. It was termed Tellurium by Klaproth, in 1798. The metal exists to the extent of 92·5 per cent. in the ore; tellurium has a silver white colour and laminated texture like antimony; brittle, pulverizable; spec. grav. 6·32. It melts at a little above 606°, and boiling evaporates; when cooled slowly, it crystallises. Before the blowpipe it ignites, and tinges the flame green.

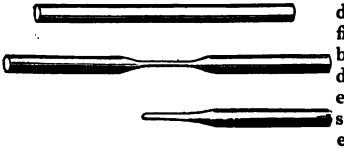
Tellurous acid appears on burning tellurium in the air, in the shape of a white smoke; or by dissolving the metal in nitro-muriatic acid, and diluting with water, the TeO_2 precipitates. *Telluric acid* (TeO_3) by fusing TeO_2 with nitre.

Telluretted Hydrogen, discovered by Davy, formed by mixing together oxide of tellurium, potash, and charcoal, and igniting. It is then placed in a retort and SO_3 added: the gas comes over transparent and colourless, with a smell resembling SH.

Arsenic. As. 9·5. (*Brandt*, 1733.)

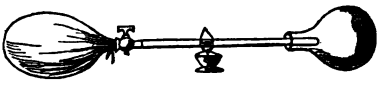
The principal ore of arsenic is arsenical pyrites, containing 43 per cent. of metallic arsenic, united with iron and sulphur (AsS FeS). The usual process for separating the arsenic consists in roasting the ore in a muffle, which is surrounded with apertures for admitting a free current of air. The arsenic unites with the oxygen of the air, and passes in the form of white fumes into a large chamber, where it condenses. This compound of oxygen and arsenic is termed arsenious acid ($As\ O_3$) or flowers of arsenic. The pure metal is obtained from this acid by what is termed the process of *reduction*. This consists in mixing intimately with the acid finely pounded charcoal, and applying heat in a close vessel. The oxygen of the acid unites with the carbon, forming carbonic acid, while the metal sublimes, or $2\ As\ O_3$ and $3\ C$ become $3\ CO_2$ and $2\ As$. The experiment may be made in a tube, which may be drawn out for the occasion, by taking a flint glass tube of the calibre of a quill; heat it over a spirit lamp at 2½ inches from one end, and holding the two ends loosely in the two hands, cause it to revolve in the flame; in a short time it will be found to soften, and may be gently drawn out, so as to form a fine point or a ball, as may be wished: the ball is produced by heating the closed end, and blowing, while still hot, from the open extremity (fig. 83.). If a few grains of arsenious acid mixed with previously ignited charcoal powder be placed at the lower end of either of these tubes and heated gently, a ring of metallic arsenic will be produced in the wider parts of the tubes. *Characters:* Arsenic has a blue colour, sp. grav. 5·8; no smell, but when heated in the open air, it is converted into arsenious acid, characterised by the smell of garlic. It sublimes at 365°. Sp. grav. of vapour, 10·37.

83 *a*



Arsenious acid ($As\ O_3$ 12·5).—*Flowers of Arsenic, White Arsenic.* This is the common form in which arsenic is familiarly known as a poison. It is generally a white powder like chalk, as sold in the shops. It occurs, however, also in a solid or glassy

84



form. It may be prepared from metallic arsenic by a beautiful combustion. Take a bladder supplied with a stop-cock (fig. 84.): fill it with oxygen gas, and tie it to the end of a hard glass tube; place a piece of metallic arsenic the size of a nut in the centre of the tube, and as soon as the metal is red-hot, turn the stop-cock and press the bladder gently; the oxygen will pass over the arsenic and excite a brilliant white combustion, while arsenious acid will fill the further end of the tube. To prevent the escape of the fumes into the air, the tube may terminate in a glass receiver. 1 part of arsenious acid dissolves in 25 parts of cold and 11 parts of boiling water. It is not therefore very soluble. It is used in medicine for the cure of ague; but when taken in over-doses it acts as a violent poison, producing burning pain in the stomach, vomiting, convulsions, weak pulse, delirium, and death. The best *antidote* is to dissolve in hot water a quantity of copperas (sulphate of iron), or, in its absence, to dissolve a piece of iron in nitric acid. When the solution of copperas is formed, nitric acid is added until the fluid, which becomes at first dark-coloured, turns of a clear yellow, heat being applied after every addition of acid. On the addition of caustic or carbonate of ammonia to this solution, the reddish-brown peroxide of iron falls. This precipitate is thrown on a calico or paper filter, and rapidly washed with boiling-hot water, until the liquid passing affords no precipitate with chloride of barium. The moist peroxide is administered to the poisoned person by taking it off the filter with a knife, and diffusing it through water in a tumbler.

Tests. — 1. When arsenious acid is boiled in a tube in sulphohydret of ammonia, it disappears, and on heating the solution the yellow sulphuret of arsenic falls ($As\ S_3$). When a person has been poisoned by arsenious acid, the stomach should be opened, having previously tied the two extremities of it, and the coats examined for a white powder which often adheres to them. This powder is to be boiled in a test-tube with sulphohydret of ammonia, which dissolves arsenious acid, and leaves oatmeal or other organic substances, with which it might be confounded. When a slip of white filtering-paper about half an inch wide is dipped into a solution of arsenious acid in this reagent, and then dried before the fire or touched with a rod immersed in dilute hydrochloric acid, it becomes yellow from the deposition of tersulphuret of arsenic ($As\ S_3$). This paper becomes colourless by immersion in caustic ammonia. 2. When subjected to the reduction test previously described, it yields a ring of metallic arsenic on the upper part of the tube. 3. *Marsh's Test.* — The contents

of the stomach are to be mixed with distilled water, heated and filtered. The filtered liquor, if it possesses a high colour, is to be mixed with pure animal charcoal, and boiled or heated until the colour disappears, and then filtered. Take a small flask; fit to it a perforated cork, into which is inserted a short quill tube about an inch in length, terminated by a capillary opening. Place in the flask (fig. 85.) an ounce of water, a few bits of pure zinc, and then pure sulphuric acid: fix the cork and tube, and having waited till the common air is expelled, light the hydrogen escaping from the tube. It burns with a pale yellow flame. Bring horizontally in contact with the flame the bottom of a white porcelain bason, and observe if any stain is left upon it. If, after five minutes, no stain is produced, we may conclude that the zinc and acid are free from arsenic. Add now a few drops of solution of arsenious acid; the colour of the flame becomes blue, and a metallic stain or spot is left on the porcelain. If this is arsenic, it will dissolve if 2 drops of sulphohydret of ammonia are poured on it and heated. A lemon-yellow is left. If antimony is present it leaves an orange stain. The only metal with which arsenic can be confounded in this experiment is antimony. In this experiment arsenious acid and hydrogen become arsenietted hydrogen and water ($As\ O_3$ and 6 H become $As\ H_3$ and 3 HO). While on being inflamed arsenietted hydrogen and the oxygen of the air produce arsenic acid and water ($As\ H_3$ and 3 O become As and 3 HO). 4. Place a clean piece of copper foil about the size of a shilling in a test-tube: add to it the solution of arsenious acid, and about 4 drops of hydrochloric acid, and boil. The copper becomes black by the deposition of arsenic. Transfer the copper to a clean dry test-tube; apply heat to the tube; arsenious acid sublimes in octahedrons into the upper part of the tube, and is prevented from escaping by placing the thumb on the mouth of the tube. In this case 3 Cu and 3 HCl and $As\ O_3$ become 3 (CuO HCl) and As. 5. To a solution of arsenious acid add a few drops of a solution of nitrate of silver. No change occurs. Dip a glass rod in caustic ammonia, and touch the surface of the solution with the moist rod, when instantly a yellow arsenite of silver ($2Ag\ O\ As\ O_3$) falls, which cannot be distinguished from the phosphate of silver. This test is therefore only of advantage in conjunction with the preceding tests. 6. Add to a solution of arsenious acid a few drops of a weak solution of sulphate of copper, so as not to colour the fluid; then touch the solution with a rod moistened in caustic ammonia, as in the preceding case. Green arsenite of copper falls ($2\ CuO\ As\ O_3$). This also is a dubious test, as phosphoric acid affords a similar result.

85

Uses. — Arsenious acid is used in medicine; in the prepara-

tions for preserving skins for museums against the attacks of insects; for anatomical preparations; and in stearic acid candles, to prevent their crystallisation. Hence there is often a perceptible smell of garlic, when a candle of this description is blown out. It is used to preserve grain; and in calico printing to convert Fe O into $Fe_2 O_3$.

Arsenic Acid (AsO_5 14·5) may be obtained by dissolving arsenic in nitric acid and evaporating, or by acting on arsenious acid with nitre and hydrochloric acid, evaporating in a crucible to drive off the nitric acid. It is a white firm mass, sp. grav. 3·391, not easily soluble in water after ignition, but under this temperature it dissolves in 6 parts of cold water. Forms *arseniates* with bases; with nitrate of silver, a brick-red arseniate of silver ($3Ag O AsO_5$). It is decomposed by heat into oxygen and arsenious acid; it unites with 3 atoms of base. Triarseniate of soda is 3 Na O As O_5 24 HO, isomorphous with triphosphate of soda.

Chloride of Arsenic ($As Cl_3$). — *Butter of Arsenic*, is obtained by distilling 6 parts of corrosive sublimate with 1 part of arsenic; a transparent and oily fluid very volatile. *Arsenietted Hydrogen Arseniohydric Acid*, $As H_3$. A gas obtained as already described under the tests for arsenic, or by dissolving an alloy of tin and arsenic in hydrochloric acid: a colourless gas, burning with a blue flame, and depositing the metal. Sp. grav. 2·695. Liquid at —22°.

Bisulphuret of Arsenic or *Realgar* (AsS_2, 13·5), occurs native, and may be formed by heating 2 parts of arsenious acid, and 1 of sulphur, together; red prisms, volatile by heat. It enters into the composition of the *Indian* or *white fire* of theatres, which is made by pounding and drying separately by the heat of boiling water, 24 parts of nitre ($KONO_5$), 7 flowers of sulphur, and 2 of realgar, or 1 of charcoal. Pile the powder made in this proportion on an iron plate, and heat it by a lamp placed below; it burns with a fine white flame. *Tersulphuret of Arsenic*, (AsS_3, 15.5). *Yellow Orpiment* occurs in nature, and may be formed by precipitating arsenious acid by sulphohydric acid (SH); it has a lemon yellow colour, tasteless, and soluble in alkalies, somewhat soluble in water, but not in water acidulated. It is the basis of King's yellow colour. Realgar and orpiment are both poisonous.

Antimony. Sb. 16. (Stibium, *Valentine*, 1490.)

Antimony occurs in nature united with sulphur in the form of black metallic prisms ($Sb S_3$). To separate it from the sulphur the ore is fused in a pot, having an aperture at the bottom, through which it flows into a vessel placed beneath. It is then roasted in a reverberatory furnace, that is, by a fire which plays upon the surface of the fused ore. The effect of this process is to drive the sulphur away, and substitute in its stead the

oxygen of the air, or $Sb\ S_3$, becomes $Sb\ O_3$. To remove the oxygen, the roasted ore is mixed with charcoal powder and a little carbonate of soda, and heated ($2Sb\ O_3$ and $3C$ become $2Sb$ and $3CO_2$), so as to remove the oxygen in the form of carbonic acid, *Characters:* Antimony thus obtained has a silver-white colour, a fibrous texture, and crystallizes by fusion and slow cooling in octahedrons. When heated to whiteness, and thrown on the table it burns, giving out much vapour. Sp. grav. 6·75. Melts at 797°.

Teroxide of Antimony, Sesquioxide ($Sb\ O_3$, 19·), obtained by decomposing the sulphuret of antimony by hydrochloric acid, filtering the liquor without the addition of water, and then dropping the solution into a pint or two of water. A white crystalline powder falls, which, when washed, constitutes the *Powder of Algaroth*, named from its first preparer ($2\ Sb\ Cl_3 + 9\ Sb\ O_3$). When carbonate of potash is digested on this substance the chlorine is removed, and an atom of oxygen substituted: thus we procure the pure oxide, which is to be filtered and washed (SbO_3). Oxide of antimony unites with acids, forming salts. The most important of these compounds is the *Potash-tartrate of Antimony*, or *Tartar emetic* ($KO\ SbO_3\ C_8\ H_4\ O_{10} + 2HO$). The process for the formation of this salt consists of three stages:— 1. The formation of the impure oxide from the sulphuret, as described, by dissolving in HCl, and filtering. ($Sb\ S_3 + 3H\ Cl$ become $Sb\ Cl_3 + 3SH$.) 2. Pouring this into water, washing and drying, $Sb\ Cl_3 + 3HO$ become $SbO_3 + 3HCl$. 3. Boiling this oxide with bitartrate of potash (cream of tartar), until it is dissolved, and then crystallising the tartar emetic by evaporation. In this stage the SbO_3 is combined with the bitartrate of potash, or $C_8\ H_4\ O_{10} + KO\ HO$ with $Sb\ O_3$, are resolved into the preceding formula. Tartar emetic usually is crystallized in 4-sided figures (tetrahedrons) with a pearly lustre. It is used as an emetic. The sulphuret is used to fatten turkeys, by enlarging their livers. There is a series of salts formed upon the same model with tartar emetic, and hence they have been called emetics. Thus, we have lead emetic ($PbO,\ AsO_3\ C_8\ H_4\ O_{10}$), iron emetic, &c. *Antimonious acid* (SbO_4), a white powder insoluble in HCl, procured by dissolving antimony in nitric acid, and evaporating to dryness. *Antimonic acid* (SbO_5, 21), obtained by fusing antimony in powder with nitre, washing the fused mass with water, and boiling with hydrochloric acid to remove potash: a straw-coloured powder, insoluble, tasteless. *Chlorides of Antimony.*— There are several compounds of this description, but the butter of antimony ($Sb\ Cl_3$) is the only one of interest. It is prepared by distilling in a retort 3 parts of corrosive sublimate with 1 part of antimony. Grayish solid, fuses at 212°, and resembles an oil. When exposed to the air it smokes. *Antimonietted hydrogen* $Sb\ H_3$? a gas (Despretz). The *Hydrous tersulphuret* is orange.

CHROMIUM. Cr. 3·5. (χρωμα, *colour*, *Vauquelin*, 1797.)

White metal, with a shade of yellow, brittle, very infusible, with difficulty soluble in aqua regia. Spec. grav. 5·9. Procured by igniting to whiteness the green oxide of chromium made into a paste with oil, in a covered clay crucible. Occurs in the octahedral chrome iron ore, an isomorphous analogue to magnetic iron ore. Its composition may be represented by 4 Fe O, 3 Cr_2 O_3, Al_2O_3. It is found also as chromate of lead in Siberia.

Protoxide (Cr O 4·5). — Brown in the hydrous state: obtained by precipitating the protochloride by caustic soda. It is gradually converted into the protosesquioxide Cr O Cr_2 O_3; it forms salts.

Sesquioxide (Cr_2 O_3 10·). — Green powder, infusible; or in greenish, black, and hard octahedrons, spec. grav. 5·21, by passing chlorochromic acid through a red-hot glass tube. Usually prepared by boiling the orange bichromate of potash dissolved in water with hydrochloric acid and alcohol. The chromic acid is deprived of half its oxygen by the carbon of the alcohol, and converted into carbonic acid (4 Cr O_3 becoming 2 Cr_2 O_3 and 3 CO_2); the oxide is then precipitated by boiling with caustic ammonia. It may be also prepared by igniting chromate of mercury; by igniting 2 parts of bichromate with 3 sal ammoniac, and 2 carbonate of potash. The hydrous green oxide forms green salts with bases; but when ignited it burns like tinder, and is insoluble in all acids, requiring then to be fused with nitre; the salts are sweet and poisonous. It is used as a green pigment, and is the colouring matter of emerald. 100 Sn O_2 33 chalk and 1 Cr_2 O_3 form *English Pink*, much used for painting on porcelain.

Chromic Acid (Cr O_3 6·5). — Rich crimson needles, or a red fusible mass, deliquescent, staining the skin yellow, forming a yellow solution in water. Obtained pure by distilling 4 parts chromate of lead, 3 fluorspar, and 5 sulphuric acid, in a lead retort with a gentle heat; a red gas comes over and condenses. By evaporation the fluoric acid is removed, and the chromic acid remains. 2. Dissolve bichromate of potash in hot water till no more salt is taken up; pour off the liquor and allow it to stand and deposit the excess of salt. When cold, pour off the solution from the salt, and mix it with twice its bulk of sulphuric acid (KO 2 Cr O_3 and 2 SO_3 become KO 2 SO_3, and 2 Cr O_3). In a few hours crystals of acid are deposited. Pour off the liquor, and spread the crystals on a porous tile, and cover them with an inverted beaker or tumbler, until the accompanying acid is absorbed. As soon as dry dissolve them in water, and evaporate in a vacuum. 3. It may be also formed by decomposing the chromate of barytes with SO_3. *Characters.* This acid readily parts with half its oxygen to bodies which have an affinity for that gas. 1. If it is dropped into

alcohol, the green oxide makes its appearance, while the peculiar smell of aldehyde is evolved ($C_4 H_5 O + HO$ becoming, at the expense of the chromic acid, $C_4 H_2 O + HO$ and $2HO$, and $Cr_2 O_3$). This is an excellent test for alcohol. 2. Place some finely pounded bichromate of potash in a platinum or porcelain capsule: pour over it some alcohol, and then some sulphuric acid. The heat and light evolved cause the alcohol to take fire. 3. Pass a current of sulphohydric acid (SH) through a solution of bichromate of potash; green oxide is deposited ($2 Cr O_3$ and $3 SH$ becoming $Cr_2 O_3$ and $3 HO$ with 3 sulphur dropped). Chromic acid unites with potash in 2 proportions: the yellow *chromate* ($KO\ Cr O_3$) obtained by fusing chrome iron ore with nitre, or by adding soda or potash to the bichromate. The orange *bichromate* ($KO\ 2CrO_3$) obtained by adding SO_3 to the chromate, is much used for obtaining the green oxide. Soda forms similar salts. The existence of these two salts in solution can be easily demonstrated by the change of colours. Place the orange solution of the bichromate in a test-glass, and add to it caustic soda, it becomes yellow; add again sulphuric acid, the orange colour is resumed. *Chromate of Lead* ($PbO\ CrO_3$).—*Chrome Yellow*, yellow powder, used for painting carriage panels, is obtained by pouring a solution of bichromate into acetate of lead. *Dichromate* or brown chromate ($2\ PbO\ CrO_3$) is obtained by digesting the chromate in caustic potash. *Chrome Vermilion*, a fine paint, obtained by fusing saltpetre in a Hessian crucible, and adding yellow chromate as long as effervescence lasts. When cool it is a fine red, owing to the formation of dichromate. A chromate and bichromate of silver exist (Dr. T. Thomson, *Phil. Trans.* 1826), and the *brown oxide* is a chromate of chromium *ib.* *Chlorochromic Acid* ($Cl\ CrO_3\ 11$) (*ib.*): fine blood-red fluid obtained by distilling in a retort with adapted receiver, 190 parts dry bichromate of potash, 225 dry common salt, and 500 of sulphuric acid: the process should be stopped as soon as the matter in the retort becomes green. 1. When dropped into water it falls like oil to the bottom, and gradually decomposes. 2. When alcohol or turpentine is dropped on it, it inflames. 3. Moist phosphorus dropped into it explodes. 4. Dropped on flowers of sulphur they catch fire. *Chlorochromate of Potassium* ($K\ Cl\ 2\ CrO_3$).—*Peligot's Salt*, is obtained by treating bichromate with HCl: flat 4-sided red prisms.

VANADIUM. V. 8·5 (*Sefstroem*, 1830.)

Only obtained as yet as a black powder; it exists as vanadic acid in vanadiate of lead, a mineral found in Siberia, at Wanlockhead and Wicklow; the metal is obtained from the acid by heating it in a tube with potassium.

Protoxide ($VO\ 9·5$); black powder, obtained by igniting vanadic acid with charcoal; very fusible, burns like tinder when ignited: it does not unite with acids. *Deutoxide* ($VO_2\ 10·5$); black powder, converted by ignition in air into the acid, formed by heating Vanadium in nitric acid, or by deoxidating vanadic acid, when in solution, by sugar, oxalic acid, or sulphuretted

hydrogen, as with chromic acid, and precipitating the deutoxide by carbonate of soda. It forms salts with acids. *Vanadic Acid* (VO_3 11·5); red when fused, rust yellow in powder, tasteless, insoluble in alcohol, very slightly soluble in water. *Test.*—Yellow with AgO NO_5: orange with BaCl; solution becomes green by oxalic acid, sugar or SH; unites with bases and forms yellow and red salts. The native vanadiate of lead (PbO VO_5 with PbCl) is the best known, although rare. It may be distinguished by reducing it to fine powder; boiling it in sulphohydret of ammonia; sulphuret of lead falls, and an orange solution is produced. Evaporating the solution, it becomes green and then blue by the addition of HCl. Vanadium unites with Cl, forming a bichloride (VCl_2), a solid; and a terchloride (VCl_3), a yellow liquid. The bisulphuret (VS_2) is a black powder.

Uranium. U. 7·5. (*Klaproth*, 1784.)

A black powder often crystalline, capable of some degree of fusion, and then possessing some ductility and malleability; burning when ignited in air; obtained from pitchblende by treatment with NO_5; on evaporating the solution a nitrate of the deutoxide is obtained. By ignition it is converted into the black oxide; this again is converted into chloride by HCl. The chloride when heated with potassium gives metallic uranium. *Suboxide* (U_2O_3, 33) Brown precipitate when ammonia is added to the subchloride. *Protoxide* (UO 8·5). *Black Oxide;* obtained in metallic plates by decomposing the yellow oxide by hydrogen gas, or decomposing in the same way the double chloride of uranium and potassium, or by precipitating the green solution of chloride by NH_3: burns like pyrophorus when heated. *Gray Oxide* (2 UO, U_3O_3 or U_4O_5 35) is the result of the calcination of the nitrate at an elevated temperature. *Olive Green Oxide* (U_3O_4 or UO + U_2O_3); dark olive green powder, obtained by treating uranium in contact with oxygen; by heat it is converted into the black oxide by losing oxygen. *Sesquioxide, Peroxide* or (U_2O_5 18) *Yellow Oxide, Uranic Acid;* a fine orange yellow precipitate; as a hydrate constitutes the basis of the yellow salts; formed by heating the ammoniacal carbonate of uranium to 570°, or by evaporating the alcoholic solution of the nitrate. This powder is used in France as a pigment for porcelain. *Protochloride* (UCl 12·); green octahedrons by passing Cl over the oxides. *Potash Chloride;* yellow rhomboidal tables. The double oxalate in yellow prisms, is procured by digesting oxalate of ammonia with oxalate of uranium.

Molybdenum. Mo. 6. (*Scheele*, 1778.)

White metal, very infusible, sp. grav. 8·62, brittle, not liable to oxidation, obtained from molybdena or native sulphuret of molybdenum, by roasting and passing it through a sieve, dissolving in ammonia, evaporating to dryness, slightly igniting. The oxide thus obtained is heated with charcoal made into a paste with oil. *Protoxide* (MoO 7·); black powder, obtained by placing a stick of zinc in a solution of molybdate of soda containing HCl; Chloride of zinc and protochloride of molybdenum are formed; by potash or soda the protoxide is precipitated in the state of a black hydrate; is converted by ignition in the open air into deutoxide; incandesces like oxide of chrome: the hydrate is soluble in carbonate of ammonia. *Test.*—HCl and NO_5 precipitate it white in strong solutions. SH produces a brown precipitate in acid solutions. *Molybdic Acid* (MoO_3 9); white powder, soluble in 570 parts of water; sp. grav. 3·5, soluble in alkalies, fusing by ignition into a yellow fluid, subliming in the form of scales, soluble in alkalies; obtained by the above process for the metal or from molybdate of ammonia, which, when heated cautiously, leaves the acid. *Molybdate of Lead* (PbO MoO_3 23·), a fine yellow mineral found in Saxony. *Deutoxide* (MoO_2, 8·); brown powder, procured by heating molybdate of soda with sal ammoniac till fumes cease, and washing the residue; insoluble in acids, changing into MoO_3 by NO_5; slightly soluble in HO; by exposure to the air it is converted into the *blue oxide*, which is a molybdate of the deutoxide. *Molybdena* (MoS_2), a well known mineral resembling graphite or black lead. *Tersulphuret* obtained in analysis, as a brown precipitate, by SH in solutions of molybdates, converted by heat into the bisulphuret. The *chloride* is obtained by dissolving protoxide in HCl.

Tungsten. W. or Tn. 12·5. (*Schecle*, 1781.)

Grayish white metal resembling steel; sp. grav .17·4; obtained by fusing wolfram in powder 3 (FeO TnO_3) 4 (MnO TnO_3) and carbonate of potash in a crucible; the tungstate of potash is dissolved out by water; sal ammoniac is added to the solution, and the whole evaporated to dryness and ignited. On digestion in water, the black oxide of tungsten remains, which, when ignited takes fire and is converted into tungstic acid. The acid is reduced to the metallic state by passing hydrogen over it at a red heat. *Oxide* (TnO_2 14·5); brown powder obtained by the preceding process. It is also obtained by placing a plate of zinc in a solution of tungsten and hydrochloric acid; copper red flocks fall. *Soda Oxide of Tungsten* (NaO 2 TnO_2 33); yellow cubic salt obtained by passing dry hydrogen over bitungstate of soda; the latter salt being formed by dissolving as much tungstic acid as tungstate of soda will take up. *Tungstic Acid* (TnO_3 15·5); pale yellow powder, sp. grav. 6·12, infusible, tasteless, insoluble in water, gives with borax before blowpipe a yellow glass; obtained by boiling wolfram in powder with a mixture of HCl and NO_5: iron and manganese are dissolved and tungstic acid remains. *Test.*—Acid solution precipitated *blue* by metallic zinc. *Bichloride* ($Tn\ Cl_2$ 21·5); red needles formed by heating the metal in Cl. *Terchloride* ($Tn\ Cl_3$ 26·); yellowish scales obtained by heating the oxide in Cl. *Bisulphuret* (TnS_2 16·5); grayish black powder procured by passing SH over tungstic acid, heated in a porcelain tube.

Columbium or Tantalum. Cm or Ta 23. (*Hatchett*, 1801. *Ekeberg*, 1802.)

Black powder obtained by heating the double fluoride of potassium and columbium with potassium; infusible, takes fire below ignition, and becomes columbic acid. *Oxide* ($Cm\ O_2$ 25); dark brown powder, obtained by heating intensely CmO_3 with charcoal, not attacked by acids, and converted into the acid by fusion with potash or nitre. *Columbic Acid* (CmO_3 26·); white powder; tasteless, insoluble, dissolved by SO_3, HCl, and some vegetable acids; forms salts with bases. *Terchloride* ($Cm\ Cl_3$ 36·5); white powder with a tinge of yellow by heating the metal in chlorine. *Sulphuret* by passing bisulphuret of carbon over the acid at a white heat. *Test.*—Fused with KO dissolves in HO. Solution precipitated by HCl: insoluble in HCl. Before blowpipe fuses into a glass with salt of phosphorus.

Columbium, Niobium, and Pelopium (*H. Rose*).

When columbic or tantalic acid, extracted from the tantalite of Bodenmais in Bavaria, is mixed with charcoal, ignited and brought in contact with chlorine, the acid becomes a yellow chloride, fusible, and volatile, and a white chloride, infusible and of little volatility. These chlorides placed in water change to metallic acids, and HCl. The acids are insoluble in hydrochloric acid, and contain a portion of 3 acids mixed. They may be almost entirely separated by treating them repeatedly with chlorine so as to separate the yellow volatile chloride (Pe Cl) from the white fixed chloride (NO Cl). The acid obtained from the yellow volatile chloride is the *pelopic acid* (from Pelops, son of Tantalus and brother of Niobe). The *chloride of columbium* requires a higher temperature to produce it than that of *pelopium*, while the *chloride of niobium* is formed at a still lower temperature than either. The chloride of pelopium volatilizes at 257°, the chloride of columbium at 291°. Chloride of columbium dissolves partially in caustic potash. Carbonate of potash has no action on it. Chloride of pelopium is more soluble in KO, and it is somewhat soluble in carbonate. Chloride of niobium dissolves completely in cold caustic potash as well as with boiling carbonate. Columbic acid is white when ignited. Columbic or tantalic acid is the acid found in the tantalite of Finland. The niobic acid, pelopic acid, are found in the tantalite of Bavaria and torreylite of America. Pelopic acid is more yellow and niobic acid possesses a still deeper colour. Before the blowpipe columbic acid dissolves

in salt of phosphorus and gives a clear bead and does not change in either flame. Pelopic acid with the same salt in the exterior flame forms a clear bead; in the interior flame it becomes brown with a violet shade. Niobic acid forms with this salt a clear bead in the exterior flame, and when the acid is considerable in the interior flame becomes a pure blue.

TITANIUM. Ti. 3. (*Gregor*, 1791.)

Copper coloured cubes; found in blast furnaces, somewhat magnetic from the presence of iron, infusible. *Sesquioxide* ($Ti_2 O_3$ 9); purple powder; obtained by placing a plate of zinc in a solution of titanic acid in hydrochloric acid. *Titanic acid* (Ti O_2 5); white powder, resembling silica, but giving with carbonate of soda before the blowpipe a yellow glass. It occurs nearly pure in the minerals Anatase, Brookite, Titanite, and also united with lime in Sphene. It may be obtained easily from titanite by fusion with carbonate of soda, and solution in HCl; by diluting with water and boiling, the acid falls in flocks. A little iron and manganese still remaining is removed by digesting in sulphohydret of ammonia and dissolving out the sulphurets in HCl. *Test:* precipitated from solutions by boiling; insoluble in HCl. (See Blowpipe Characters.) *Bichloride* (Ti Cl_2 12); colourless fluid; boils a little above 212°; sp. grav. of vapour 6·615; fumes in the air, gives out heat when water is added; obtained by passing dry chlorine over the metal at a red heat. The metal may be obtained from this compound by mixing it with ammonia, which forms a dry solid, and passing over it, at a red heat, dry ammonia; sal ammoniac sublimes and the metal remains. *Bisulphuret* (Ti S_2 7); green powder, formed by passing bisulphuret of carbon over titanic acid.

Some of the preceding bases may be readily distinguished by the following tests:—

I. *Substances soluble in sulphohydret of ammonia.*—1. *Antimony* dissolves either in the metallic or sulphuretted state, and yields by HCl, or heat, an orange precipitate (SbS_3). 2. *Arsenic* dissolves and gives a lemon yellow by HCl and heat (AsS_3). *Vanadic acid* dissolves, affording a light wine colour, the solution becoming blue or greenish by HCl. 4. *Molybdic acid* dissolves, yielding a fine claret colour.

II. *Substances rendered blue by a plate of zinc and* HCl.—1. *Tungstic acid* and soluble *tungstates*. 2. *Molybdic acid*. 3. *Titanic acid*.

III. *Blowpipe action.*—1. *Titanic acid* yields a yellow glass with carbonate of soda. 2. *Silica*, a colourless glass with soda. 3. *Columbic acid*, a colourless glass with biphosphate of soda.

NORIUM.

A metal announced by Svanberg as having been extracted by him from the Zircons of Norway, but no proof of this has yet been given. It is allied to Zirconium.

Remarks on Acid and Salt Radicals.

When oil of vitriol (HO SO_3) is poured on caustic potash (HO KO), the acid (SO_3) which previously reddened litmus paper, no longer possesses that power; a salt is said to be formed, consisting of sulphate of potash (SO_3 and KO). If we dissolve this salt in water and add Ba Cl, we obtain sulphate of barytes (Ba O SO_3) a white powder. But we have no evidence of the existence of SO_3 in this compound. The true expression may be K SO_4 and Ba SO_4, while the oil of vitriol would be H SO_4. The first mode of expressing the composition is called the *acid theory;* the second, the *salt radical theory*, and is due to Davy. The latter has the advantage of assimilating oxygen acids to hydrogen acids. Thus chlorohydric acid would be represented by this view as a chloride of hydrogen (HCl) and chloride of potassium (KCl), would be produced by the substitution of K for H. Oil of vitriol (HO SO_3) would have for its base hydrogen (H SO_4) and would, therefore, be a hydrogen acid. Nitric acid (HO NO_5) would be H NO_6, and by this view hydrogen would almost seem to be the acidifying principle. This view has no value practically.

CHAPTER V.

BASIC RADICALS.

Class I. Alkaline Bases.

Light metals decomposing cold water, and forming very soluble oxides which turn vegetable blues green.

Potassium. Sodium. Lithium.

Potassium. K. 5. (Kalium.)

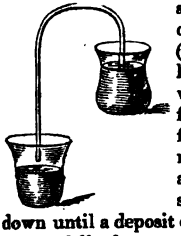
Potassium was ascertained in 1807 by Sir H. Davy, to be the basis of potash salts, by means of the galvanic battery. The theory of the best process for its separation consists in removing oxygen from the potash (KO) by means of charcoal; and for this purpose black flux is employed, a substance prepared by calcining bitartrate of potash (cream of tartar); the tartaric acid is decomposed partly into carbonic acid, which unites with the potash, the rest escaping in the form of carbonic oxide, while, from a part of the tartaric acid, carbon is separated, which is thus intimately mixed with the alkaline carbonate. This mixture, then, of charcoal and carbonate of potash, is ground with its own weight of charcoal, and placed in an iron bottle. This is deposited in a good wind-furnace, in a horizontal position; a short iron tube is fitted to the mouth of the bottle by a screw, and then is fixed into a receiver containing naphtha. The iron tube has an iron rod inserted in it, to keep it clean by stirring. When the decomposition begins, green-coloured vapours pass over; the receiver is then attached. As long as gas issues from the bent tube it is a proof that the process is going on well; but as soon as the gases cease to be evolved, the process may be considered at an end. The potassium will then be found at the bottom of the receiver contaminated with carbon, from which it may be freed by distillation from an iron bottle into a naptha receiver. In this process 2 atoms of charcoal by acting upon 1 atom carbonate of potash, produce 1 of potassium, and 3 of carbonic oxide (2 C and KO CO_2 become K and 3 CO). *Characters.* White metal: brittle at 32°; solid at 50°; fluid at 136°; sp. grav. ·865. It therefore floats on water; conducts electricity; distils at a low temperature in the form of a green vapour. Crystallises in cubes; must be preserved in naphtha.

Protoxide of Potassium (KO 6).—*Caustic Potash.* When potas-

sium is thrown on water a combustion takes place in the form of a violet flame, terminating in an explosion. The water is decomposed; the oxygen uniting with the metal, and dissolving, while the hydrogen is set free. The liquid in which the experiment is made affords an alkaline reaction. The explosion appears to be produced by the ignition of a bubble of steam. When the liquid is evaporated, caustic potash is left, a white solid body, possessing a caustic taste, and immediately destroying the mucous membrane of the mouth. When exposed to the air it attracts moisture, or it is said to deliquesce, and dissolves in acetic acid or vinegar without effervescence; dissolves in half its weight of water; dissolves in alcohol. When heated to redness it is a *protohydrate* (KO HO), sp. grav. 1·706: crystalline. *Anhydrous* potash can only be obtained by burning potassium in dry oxygen gas. Solid potash is used as a caustic to remove warts and fleshy excrescences, either in a pure state or mixed with an equal weight of lime, and kept in a stoppered bottle.

Solution of Caustic Potash, Liquor or Aqua Potassæ, Alkaline Lye — May be conveniently prepared by dissolving 1 lb. of carbonate of potash in from 10 to 11 lbs. of water, and then adding gradually ½ lb. of quicklime previously slaked and made into a cream with water. The mixture is then boiled in an iron pan for twenty minutes, taking care to replace the water as it evaporates, and never to allow it to fall below 10 lbs. The reaction is as follows: — carbonate of potash ($KO\ CO_2$), and lime (CaO) become carbonate of lime ($CaO\ CO_2$), and caustic potash (KO). If a smaller quantity of water be employed, the potash takes back the carbonic acid from the lime. The mixture is allowed to stand until the carbonate of lime subsides, and is covered close. The liquor is then drawn off with a *syphon*. This is merely a (fig. 106.) bent glass tube, one leg of which is longer than the other. It is filled with water; the long leg being stopped with the finger. The short end is then placed in the fluid to be drawn. When the finger is removed from the long leg, the liquor runs in a continued stream into another vessel. The solution, when drawn off, should be boiled down until a deposit of salts takes place. It is then to be bottled up carefully for use.

86



Tests. —1. When pure it should not effervesce with acids. 2. Tartaric acid, when in solution and added to it, should afford a precipitate of cream of tartar. 3. It yields a yellow precipitate with a solution of bichloride of platinum, when rendered slightly acid by hydrochloric acid. 4. When heated before the blowpipe

the flame is tinged violet. 5. When pure it dissolves completely in alcohol. Caustic potash is a very important body, as well as caustic soda, as a reagent in chemistry, by affording a means of separating various bodies from each other. (*See Tables*, p. 25.)

Compounds. — The salts of potash are usually destitute of colour; The chromates, uraniates, and croconates excepted. They are all soluble in water. *Chloride of potassium* (KCl 9·5). Right rectangular prisms and cubes. Taste, salt; 100 water at 32° dissolve 29; at 212°, 56½. Prepared by dissolving carbonate of potash in hydrochloric acid, and from kelp. *Cyanide* (K Cy) colourless cubes, obtained as described p. 83.

Iodide of Potassium (KI, 20·75). — Colourless cubes. The process for its preparation consists of two stages. 1. An iodide of iron is formed by heating 3½ parts iron filings, 15¾ iodine diffused in water. Iodide of iron (Fe I) speedily exists in solution. 2. When the colour of the preceding liquor has become green, it is mixed with 2 parts of carbonate of potash previously dissolved in water. The liquid is then filtered, and the iodide crystallized by evaporation. It is used in 3-grain doses in rheumatism, and also for Daguerreotype processes. *Bromide of Potassium* is made in a similar way. *Sulphuret of Potassium* (KS), a red crystalline body, is formed by heating to whiteness 4 parts sulphate of potash with 1 of charcoal.

Carbonate of Potash ($KO\,CO_2$, 8·75). — *Fixed Nitre, Salt of Tartar.* Octahedron with a rhombic base. Obtained by burning plants and trees. The ashes which remain are digested in water, the liquor filtered and evaporated to dryness. The remaining salt is termed in commerce *potash*, and consists of all the soluble salts which usually exist in vegetables, including carbonate, sulphate, and phosphate of potash, chloride of potassium, with unburned charcoal. When this potash is heated to redness, it becomes white by the combustion of the charcoal, and is then known under the name of *pearlash*. The determination of the amount of potash contained in pearlash constitutes the test upon which its value as an article of commerce depends, and is termed *Alkalimetry* (measure of the alkali). A convenient method is to dissolve 50 grains of the potash in 2 ounces of water in a flask or phial: 60 grains of well crystallized oxalic acid are reduced to powder, and weighed out in a tube or carefully balanced piece of paper. Small portions of the acid powder are then to be added at a time, by means of a spatula or point of a knife, to the alkaline solution, shaking the liquid between each addition, heating and testing with litmus paper, until the latter becomes slightly reddened while the liquid is hot. The residual oxalic acid is then weighed. Suppose it to be 20 grains. It is obvious that to saturate 50 grains of the sample, 40 grains of oxalic acid have been required. We say then that the relation between the atomic weight of oxalic acid

and of carbonate of potash, is the same as between the quantity of oxalic acid employed and the carbonate of potash or 50 grains of the sample; or as 7·875 : 8·75 :: 40 : 44·4. If we multiply 44·4 by 2, we get the amount of carbonate of potash in 100 parts of the sample. We say then that the specimen submitted to examination contained 88·8 per cent. of alkaline carbonate, and by the proportion 8·75 : 88·8 :: 6 : 60·8, we find the 88·8 parts of carbonate to contain 60·8 parts of potash, or alkali.

A similar process may be conducted by means of any other acid in a liquid form.

Bicarbonate of Potash ($KO\,2\,CO_2\,HO$, 12·5).—Right oblique prisms, sp. grav. 2·012, soluble in 4 times its weight of water, almost insoluble in alcohol. It is formed by passing carbonic acid into a vessel or chamber containing carbonate of potash in the state of a saturated solution or in powder. This is the purest form in which potash can be employed.

Nitrate of Potash ($\dot{K}O\,NO_5$, 12·75).—*Nitre or Saltpetre.* Right rhomboidal prisms; generally in 6-sided channelled prisms, terminated by 6-sided pyramids. Taste, bitter or cooling. Sp. grav. 1·933. Nitre is found on the surface of the earth in India, Ceylon, and Spain, intermixed with soils containing animal matter. Hence the most probable source of nitre is the oxidation by the oxygen of the air of the ammonia evolved from the animal matter. Nitre is artificially prepared in Germany and France, in what are termed artificial nitre beds. These are formed by placing alternately strata of earth, containing carbonate of lime or old mortar, rubbish and dung over each other, so as to form a pyramid, which is kept moist with the fluid draining from dung-hills. Nitre is thus produced in considerable quantities in two years. The nitre earth of India consists of nitrates of lime, potash, and magnesia, with common salt, carbonate of lime, &c. It is well washed with an equal quantity of wood ashes to unite the nitric acid with potash. The liquors are evaporated and further purified by crystallization. To determine the amount of common salt in a sample of nitre, with which it is usually contaminated, we dissolve 50 grains of nitre in a test glass. Dissolve then 42·5 grains of nitrate of silver in an alkalimeter (fig. 107.) graduated into 100 degrees; drop this solution into the hot solution of nitre, mixed with nitric acid, until a precipitate of chloride of silver no longer falls: if the whole of the test nitrate liquor is required, it indicates the presence of 15 grains of common salt in the 50 grains of nitre. Then by the proportion as 100 : 15, so is an intermediate quantity as indicated by the alkalimeter to the equivalent amount of common salt.

87

Nitre may be produced by boiling nitrate of soda with chloride of potassium ($NaO\ NO_5$ and K Cl forming $KO\ NO_5$ and Na Cl). When the price of these salts is low, this may prove an economical process. Nitre is important in the manufacture of gunpowder and in fire-works. — *A subaqueous or under-water match* is made by mixing 400 parts nitre, 200 gunpowder, 200 charcoal, and 100 sulphur, all well dried and triturated, and introducing them tightly rammed down into a paper tube formed by rolling a piece of cartridge paper round a ruler or rod. When set fire to and plunged under water, it burns most violently. — *Portfire* is made by triturating in a mortar 300 grains of nitre, 200 sulphur, and 100 gunpowder, carefully dried, and packed into a paper tube, as described. It burns with a fine flame. — *Gunpowder* consists of 76 parts of nitre, 13 charcoal, and 11 of sulphur, moistened with water, ground and pressed through sieves perforated with round holes, and dried by a steam heat. The explosive power of gunpowder depends upon the instantaneous production and expansion of carbonic acid, sulphurous acid, and nitrogen. When gunpowder is spread on an iron plate, and cautiously heated with a lamp placed below it, no explosion occurs, but the sulphur takes fire and burns; and it is not till the powder is heated above 500°, that any explosive combustion occurs.

Squibs are made of 24 parts mealed or finely ground powder, 4 charcoal, 1 sulphur, 3 nitre. — *Chinese fire* of 16 parts meal powder, 2 sulphur, 5 iron filings. — *Ancient fire*, 16 meal powder, 2 charcoal. — *Brilliant fire*, 16 meal powder, 4 iron filings. The preceding packed into paper cylinders, or goose quills, and ignited. — *Gold rain*, to descend from a rocket like a shower, is made by mixing 16 parts nitre, 4 mealed powder, 4 sulphur, 1 brass dust, 2¼ saw dust, ¼ glass dust. (*Capt. Griffiths.*)

Glass. — This term is by some supposed to be derived from *glacies*, ice, and by others from *glastrum*, woad or blue, from its having a blue shade. There are four kinds of glass in use: 1. *Bottle glass* or *green glass*, is formed in this country by fusing in an earthen pot, inserted in a glass-house furnace, 3 parts of soapers' waste (principally carbonate of lime), with 1 part of river sand, for 18 hours. The resulting green glass is therefore a silicate of lime. 2. *Crown* or *window glass* is made by fusing 1 part of Lynn or Isle of Wight sand, and 2 parts of kelp or carbonate of soda. It is a silicate of soda, lime, and alumina. 3. *Flint*, or *common table glass*, is so named because it was originally made with flints. It is now made by fusing 1 part of pearlash (carbonate of potash), 2 parts of red lead, and 3 of sand, with sometimes a portion of saltpetre, for 30 to 48 hours. Flint glass is a silicate of potash and lead. Tumblers, glasses, decanters and our common crystal are made of this glass. 4. *Plate glass* is

principally a silicate of soda and lime, and is one of the most difficult glasses to make. It is formed by fusing fourteen parts of Lynn sand, 4¾ anhydrous carbonate of soda, and two parts of quicklime. For the preparation of glass, it is necessary that the sand should contain as little iron as possible, and should be previously ignited to destroy any carbonaceous matter which may be present.

Sodium.

Na. (Natrium) 3. Sodium occurs in nature in various states of combination, as chloride of sodium or common salt in sea water and in vast deposits in the new red sandstone formation in Cheshire, as sesquicarbonate in the north of Africa, nitrate of soda in Peru, &c. Sodium is obtained by decomposing the oxide of sodium, or solid caustic soda, by means of the galvanic circuit, or by heating intensely in an iron bottle a mixture of soda and charcoal — as in the production of potassium. It is a white metal, solid at the usual temperature, malleable, and so soft that it may be welded by pressure; specific gravity ·972; melts at 194°; less volatile than potassium. In the air becomes encrusted with caustic soda. When thrown on cold water it gradually unites with the oxygen, disengages hydrogen, and dissolves in the fluid, which acquires an alkaline reaction; when thrown on hot water it burns, emitting a *yellow* flame.

Protoxide of sodium, caustic soda, NaO 4·, formed when sodium decomposes water. It is also prepared from the common carbonate of the shops, by means of lime, according to the same process as that used in the preparation of potash; one pound of carbonate of soda is boiled with half a pound of quicklime, and ten pounds of water. In this country caustic soda is usually employed for the same purposes to which potash is applied on the continent. All the soda of this country is prepared from common salt, which is abundant, and therefore cheap; while abroad potash is derived from the ashes of trees and plants. Liquid caustic soda does not precipitate the alkalies, but it throws down the earths, redissolving in excess alumina and glucina. It precipitates most of the metals, redissolving zinc, tin, and lead. When the solution of caustic soda is evaporated, a white solid remains, which is a hydrate of soda. Pure soda, free from water (NaO) can only be obtained by burning sodium in dry oxygen at a high temperature. It is a gray mass; specific gravity 2·805. Non-conductor of electricity. Melts in a strong heat. It is characterised, like all the salts of soda, by yielding to the flame of a candle a yellow colour. A *peroxide* (NaO_3) of sodium is procured by burning sodium in dry oxygen, at a lower temperature than the preceding. It is a greenish yellow powder.

Chloride of sodium, common salt, rock salt, kitchen or culinary salt, muriate of soda, Na Cl 7·5, crystallizes in cubes, or in figures of six equal sides. The great source of this salt is the ocean, from which it has been deposited by evaporation, as is proved by its being contaminated by salts, which occur in sea water. It may be formed pure by dissolving carbonate of soda in hydrochloric acid and crystallizing. When extracted from the earth it is dissolved in water, and evaporated to free it from iron. Specific gravity 2·03. Taste salt. It is employed for preserving meat, which it effects by removing the water contained in the animal fibre. With the same object it is used for the preservation of animal and vegetable preparations.

Carbonate of soda, hydrous carbonate, soda crystals $NaOCO_2$ 10HO 18·; right rhombic prism. *Taste* alkaline; litmus paper is tinged green by it. It is seldom seen in a perfect state in commerce, in consequence of the great tendency it has to lose water, but usually appears as a white powder—(Scotch soda in London). This salt is made from common salt, by heating it with sulphuric acid (Na Cl + SO_3 HO, becoming NaO SO_3 and HCl). Hydrochloric acid is set free and passes off, and hence soda manufacturers, when they do not condense this acid, allow it to pass into the atmosphere by a tall chimney, to prevent it from injuring the surrounding vegetation. The sulphate of soda is then converted into carbonate of soda by heating it with carbonate of lime (limestone) and coal. It first becomes sulphuret of sodium (Na OSO_3 and 4 C become NaS and 4CO): the sulphuret is then carbonated by the limestone and coal (NaS and $2CaOCO_2$ and C becoming $NaOCO_2$, CaS + CaO, and 2CO). The carbonate of soda is dissolved out from the sulphuret of lime, purified and crystallised. What is called *soda ash* is a mixture of dry caustic soda and carbonate of soda: in this state it is usually employed by bleachers and other manufacturers, as the crystals contain more than half their weight of water. To prepare this soda for making soap, it is boiled with lime, converted into caustic soda, and is then mixed with the requisite quantity of fat or oil, and boiled.

Bicarbonate of soda. NaO CO_2 HO CO_2 10·625. This is a white powder, usually employed for making effervescing powders, under the names of Seidlitz powders, soda powders, &c. It is prepared by spreading out common crystallised soda in a close leaden apartment, and sending over carbonic acid, so as to fill the empty part of the chamber with this gas. The salt gradually takes up an additional atom of carbonic acid. It is much used in the preparation of bread by the unfermenting plan. The dough is mixed with the salt, and then water containing hydrochloric acid is stirred through it. An effervescence takes place from the disengagement of carbonic acid, which is expelled by the

heat, and raises the bread, while common salt remains to season it ($NaO2CO_2$ and HCl becoming Na Cl, HO and $2CO_2$). To make a soda or *effervescing powder* it is only necessary to take nearly equal weights of bicarbonate of soda and tartaric acid; to dissolve the soda first in half a tumbler full of water, and then to add the tartaric acid, and stir with a spoon or glass rod. *Sesquicarbonate of soda* occurs sometimes in the preceding process in crystals ($2NaO\ 3CO_2\ 4HO$).

Sulphate of soda, Glauber salt. — $NaO\ SO_3\ 10\ HO$ 20·25. This salt occurs in some waters, though rarely; but it is usually obtained by the decomposition of common salt, as in the first stage of the preparation of carbonate of soda. It crystallizes in channeled 6-sided prisms, or rather 4-sided rhombic prisms, with two edges replaced. When heated, it becomes fluid, when it is said to undergo the *watery fusion*. A very curious experiment can be made with this salt. If $1\frac{1}{2}$ lb. of the sulphate be dissolved in 1 lb. of boiling water, and the solution be allowed to cool in a vessel which is tightly corked up, on uncorking it or throwing a solid body into this solution, the whole becomes speedily a solid mass, apparently from the susceptibility to crystallization in that condition. The temperature of the solution rises. This salt is used as an aperient, more particularly for horses and cattle. *Bisulphate of soda*, $NaO\ 2SO_3\ 2HO$.

Phosphate of soda, Trisphosphate of soda, Tribasic phosphate. — $2NaO\ HO\ PO_5$, 24HO 45·125. Oblique rhombic prisms, obtained by adding a solution of carbonate of soda to the phosphoric acid procured from bones by the process described, and evaporating; taste, saline; effloresces or becomes a white powder in the air, soluble in four times its weight of water. No action on litmus. *Pyrophosphate*, or *Disphosphate of Soda*, $2\ NaO\ PO_5\ 10HO$, obtained by igniting the preceding salt. The former gives a yellow precipitate with nitrate of silver, $3AgO\ PO_5$, while the ignited salt gives a white precipitate ($2\ AgO\ PO_5$). *Metaphosphate* or *Monophosphate of soda* ($NaO\ PO_5$) is obtained by heating biphosphate of soda ($NaO\ HO\ PO_5\ 3\ HO$); when dissolved in water, this salt gives a precipitate with nitrate of silver, having only one atom of base ($AgO\ PO_5$). *Ammonia Phosphate of soda, Salt of phosphorus, Microcosmic salt.* — $NH_3\ NaO\ PO_5\ 10HO$. Doubly oblique prisms, formed by heating 6 parts phosphate of soda, 1 of water, and 1 hydrochlorate of ammonia. It is used as a blowpipe flux. *Ammonia phosphate of magnesia*, $NH_3\ 2MgO\ PO_5$ 13HO. Rectangular prisms or granular powder nearly insoluble in water containing caustic NH_3, obtained by adding to a salt of magnesia a solution of phosphate of soda and carbonate of ammonia; it is the salt formed in the usual mode of precipitating magnesia.

Antimoniate of soda, $NaO\ SbO_5\ 7HO$. White crystalline

powder, is formed by pouring a solution of antimoniate of potash into a solution of a salt of soda, and is hence an excellent test for soda. The *antimoniate of potash* is prepared by igniting in a clay crucible 1 part of antimony with 2½ of nitre, washing the mass free from soluble salts, and calcining the residue with half its weight of dry carbonate of potash. Boiling water takes up antimoniate of potash, which is used as a test for soda salts.

Arseniate of soda, Trisarseniate, HO $2NaO$ AsO_5 24HO, obtained by saturating carbonate of soda with arsenic acid. Oblique rhombic prisms isomorphous with *triphosphate of soda.*

Borax, biborate of soda. NaO 2 BO_3 10HO. — Octangular prisms, specific gravity 1·74, renders vegetable blues green. Soluble in twenty times its weight of water; brought from Thibet, under the name of *Tincal;* but it is also made by saturating carbonate of soda with Tuscan boracic acid.

Nitrate of soda — Cubic nitre. — NaO NO_5 10·75. Rhomboids, found in large quantities in Peru, in strata of 2½ feet thick, probably the deposit from a lake. It is used for the preparation of nitric acid, and also in the manufacture of sulphuric acid. In consequence of its deliquescence, it is not fitted as a substitute for nitrate of potash in the manufacture of gunpowder. It may be formed by saturating carbonate of soda with nitric acid. It is much more soluble in cold water than potash nitre.

Tests for Potash and Soda. — When bichloride of platinum in solution is added to a salt of potash, dissolved in a small quantity of water, a lemon yellow precipitate falls, *Potassium bichloride of platinum* (K Cl. $PtCl_2$), every 30·75 grs. containing 5 of potassium or 6 of potash. When the quantity of potash is to be estimated, this precipitate must be washed with alcohol of 60 per cent., in which it is insoluble, and weighed upon a filter, the weight of which is previously ascertained. Potash salts give a *violet* colour to the blowpipe flame, and are precipitated as cream of tartar by tartaric acid. Soda salts are precipitated by antimoniate of potash, as a white crystalline powder, and impart a *yellow* colour to the blowpipe flame.

Lithium L. 0·75. — White metal separable from its oxide by electricity. *Lithia,* LO 1·75. — White substance, resembling potash and soda, obtained by heating 1 part of petalite or spodumene with 2 parts of fluorspar, and 3 or 4 of SO_3 in a platinum vessel. The silica is volatilized in union with the fluorine. After separating the other sulphates, there remains sulphate of lithia. Lithia forms soluble salts with SO_3 and C_2O_3 and CO_2. The chloride crystallizes in cubes, which dissolve in alcohol, and impart a red colour to its flame.

BASIC RADICALS.

Class II. Metals of Alkaline Earths.

Barium. Strontium. Calcium. Magnesium.

The alkaline earths are four in number: Barytes, Strontian, Lime, and Magnesia: the three first are distinguished by yielding no precipitate with ammonia, and falling when soda or potash is added, while magnesia does not fall with ammonia if salts of NH_3 be present.

Barium.

Ba. 8·5. — This metal is obtained by exposing the hydrate of barytes (BaO HO) to the action of a galvanic battery, in contact with mercury. An amalgam of barium and mercury forms, from which the latter distils off when heated, leaving the pure barium behind. (*Davy.*)

Protoxide of barium, barytes, heavy earth, terra ponderosa. BaO 9·5. This oxide occurs abundantly in nature, associated with lead ore, in union with sulphuric acid, as sulphate of barytes or heavy spar. To render this very insoluble substance soluble in water, it is to be heated with an equal bulk of finely pounded charcoal in a clay crucible, covered over with sand, and exposed for some hours to a strong red heat. By the charcoal, all the oxygen is removed from the mineral, and sulphuret of barium remains ($BaO\ SO_3$ and $2C$ becoming BaS and $2CO_2$), which is quite soluble in water. If the solution be now precipitated by carbonate of NH_3, the carbonate of barytes dissolved in NO_5 and crystallized, $BaO\ NO_5$ remains; by ignition, the nitric acid is driven off, and barytes (BaO) remains. A grayish white solid; taste, caustic; a violent poison; tinges vegetable blues green; fuses before the blowpipe into globules; attracts water in the air, and slakes like lime; 100 parts of cold water dissolve 5 parts of barytes; boiling water more than half its weight.

Peroxide of barium — BaO_2 10·5, is obtained by passing oxygen over barytes in a porcelain tube. Gray powder, not decomposed at a red heat, but by boiling water, and acids. *Chloride of barium* — Ba Cl. 2HO 15·25, may be obtained by boiling a solution of the sulphuret (procured by the process already

described) with hydrochloric acid, until all the sulphuretted hydrogen passes off; on evaporation it crystallizes in white rhombic prisms, or plates. Taste, bitter; poisonous. It is an important re-agent for detecting and estimating sulphuric acid quantitatively. *Nitrate of barytes.*— BaO NO_5 15·25, 8-hedrons, obtained by neutralising the carbonate of barytes with nitric acid, and crystallising. 12 parts of water at 60°, and 3 or 4 of boiling water, dissolve 1 part of the salt; insoluble in alcohol. It is a useful re-agent, as in the distillation of nitric acid, for the separation of sulphuric acid. It affords the *green fire* of fire-works and theatres. This is made by mixing in a mortar 100 parts of nitrate of barytes, previously well dried, with 9 sulphur, 7 chlorate of potash, 2 of charcoal, and 4 sulphuret of antimony, all well dried. If a small heap of this is formed upon an iron plate, and heated by a lamp placed below, and touched immediately with a hot wire, a beautiful green combustion will take place after some time.

Test.—The salts of barium are distinguished by the green colour they afford to the flame of the blowpipe. The experiment may be made by holding the salt in a pair of forceps, or in the loop of a platinum wire, or by dipping a platinum wire in a strong solution of the salt: they are also distinguished by their affording an immediate precipitate to a solution of sulphate of lime, lime giving none; and strontian only after the lapse of some time; oxalic acid gives no precipitate in dilute solutions.

Strontium.

Sr. 5·5. Strontium is obtained from strontian (SrO) in the same way as barium from barytes, as already described. The name is derived from the village of Strontian, in Argyleshire, where the substance was first discovered. Strontium is white, solid, and heavy, decomposing water, and absorbing oxygen from the air. —(*Davy*).

Strontian, protoxide of Strontium, Strontites, Strontia, SrO 6·5, may be obtained from the sulphate of strontian or celestine, by the same process as described for barytes. The oxygen is removed from the mineral by means of charcoal, and the resulting sulphuret dissolved in water and neutralised by nitric acid or carbonate of soda, or ammonia. The nitrate or carbonate when strongly heated leaves caustic strontian (SrO), a grayish white mass with an acrid and alkaline taste, not poisonous, soluble in 50 times its weight of cold water (60°) and in twice its weight of hot water (212°). The solution, when evaporated, deposits square plates containing 68 per cent. of water. Strontian slakes like lime, and forms a hydrate (SrO HO). The solution turns vegetable blues green; insoluble in alcohol. *Peroxide of Stron-*

tian, SrO_3 7·5, is obtained in bright scales when a solution of strontian is mixed with deutoxide of hydrogen. *Chloride of Strontium*, Sr Cl 9 HO, 6-sided prisms, obtained by dissolving the carbonate in hydrochloric acid and crystallizing; a deliquescent salt, soluble in water and alcohol. The solution in alcohol, when set on fire, burns with a beautiful crimson flame, characteristic of the salts of Strontium. *Nitrate of Strontian*, SrO NO_5 13·25, anhydrous octahedrons or oblique prisms, with 30 per cent. water, insoluble in alcohol. This salt is used in the preparation of the *red fire* of fire-works — 100 parts of dry nitrate of strontian are carefully mixed with 12 parts of chlorate of potash, 30 sulphur, 10 sulphuret of antimony, and 5 charcoal, all carefully dried, and rubbed with great caution in a mortar to prevent friction, otherwise an explosion may occur. The powder is heaped up on a thin iron plate and heated from below by means of a lamp, and then touched with a hot wire.

Tests. — Salts of Strontian are recognised by their giving, with a solution of sulphate of lime, a precipitate only after some time. Oxalic acid affords no precipitate; while lime yields one at once. The salts of Strontian when heated in the blowpipe flame impart a crimson colour to it, as do their solutions. Their solution in alcohol burns with a fine crimson flame.

Calcium.

Ca 2·5. A white metal, similar to barium and strontium, and obtained by the same process. — (*Davy*).

Protoxide of Calcium, Lime, quicklime, caustic lime, burned lime, CaO 3·5, is obtained by burning carbonate of lime, limestone, or chalk in a limekiln, along with coal. The intense heat produced expels the carbonic acid (CaO CO_2 becoming CaO and CO_2 set free). This experiment may be imitated by heating a splinter of marble or limestone before the blowpipe. Lime is white and easily pulverised. — Specific gravity 3·16. Hot taste and burning, destroying animal substances; tinges vegetable blues green, and gradually turns them yellow. Very refractory, and has never been fused except by the oxyhydrogen blowpipe. It glows or phosphoresces when exposed to a full red-heat. When pure it does not effervesce with dilute acids, and its solution does not precipitate prussiate of potash or caustic ammonia. *Hydrate of lime.* — *Slaked lime*, CaO HO 4·625. When a few drops of water are poured upon a piece of quicklime they are immediately absorbed. If a larger amount is added heat is evolved, while vapour, and sometimes light, appear. The heat is so considerable that vessels loaded with lime have been set on fire, and an apparatus, consisting of a kind of cabinet of tin drawers, has been constructed, where, by placing

slaking lime in a lower drawer and meat in that immediately over it, sufficient heat is evolved to cook a beef steak or mutton chop. This method of producing heat is said to have been practised by Mr. Green in his celebrated balloon voyage from London to Wiesbaden in one night. This operation is very familiar under the term of *slaking* lime, and may be seen every day where mortar is preparing. The evolution of heat depends on the fact that in all chemical combinations heat is given out. In the present example, the water unites with the lime, and, becoming solid, loses the heat which was necessary to retain it in a fluid form. During slaking the vapour given off renders vegetable blues green, and has a smell owing to a portion of the lime being carried with the vapour. Pure lime (CaO) is incapable of absorbing carbonic acid; but when it is slaked (CaO HO) it readily takes up carbonic acid, which replaces the water (CaO HO and CO_2 becoming CaO CO_2 and HO). Hydrate of lime dissolves sparingly in water — forming *lime water* — 1 part of lime dissolving in 778 parts of water at 60° — in 972 water at 130°, and in 1270 water at 212°. Lime-water is best prepared by throwing a quantity of pounded lime into a stoppered bottle filled nearly full of water, and allowing it to stand for some days, with frequent agitation. The clear liquor is then poured off or filtered away from the air. In contact with the atmosphere a pellicle of carbonate of lime soon forms on the surface from the absorption of carbonic acid from the air. It must therefore be preserved in well stoppered bottles. On the addition of water containing carbonic acid to lime water there is a precipitate of carbonate of lime, which disappears on the addition of a larger quantity of carbonic acid (CaO CO_2 and CO_2 becoming CaO $2CO_2$, a soluble bicarbonate), in which state carbonate of lime exists in well and river waters. Lime-water is useful for the detection of carbonic acid, and for the diarrhœa of infants, to whom it may be given mixed with their milk. Lime is employed as a mortar to cement stones together, in consequence of its tendency to unite with water, carbonic acid, and sand or silica, and to set or harden during the combination. It is made best by mixing 1 part unslaked lime, 1 slaked lime, 1½ fine and 1 coarse sand. Lime is also used as a manure for land, in consequence of its action in decomposing vegetable substances, and from its effect on alumina or clay. Thus when pipeclay and *milk* or *cream of lime* (hydrate of lime made of the consistence of cream by the addition of water) are mixed the whole becomes thick on agitation, and when left in contact for some months the mixture assumes the appearance of a jelly; on the addition of an acid, the clay is broken up by the union of some of its constituents with lime, and any alkalies present are set free. One essential use in applying lime to land

appears therefore to be to liberate the alkalies in union with silica in the soil. Marl or carbonate of lime, when dissolved in water by an additional atom of carbonic acid, exercises the same effect on soil. *Peroxide of Lime.* — CaO_2 4·5. — White brilliant scales obtained by dropping lime-water into peroxide of hydrogen. *Chloride of Calcium*, Ca Cl 7·, exists in sea and mineral waters. It crystallizes in 6-sided prisms with 6 atoms of water. As usually prepared for use, it is made by saturating chalk or marble ($CaO\ CO_2$) with hydrochloric acid, evaporating the solution to dryness, and heating up to 350°, to remove the crystalline water. Taste bitter and sharp — deliquescent. The crystallized salt, when mixed with snow, produces intense cold. The dry salt is employed to dry gases when transmitted through tubes, fig. 45.

Bleaching Powder, Tennant's Bleaching Powder, Hypochlorite of Lime, Chloride of Lime. Berthollet first introduced chlorine as a bleaching agent. It was used afterwards in solution under the name of Eau de Javelle, when water was impregnated with it. In January 1797, Charles Tennant, of Darnley, near Glasgow, obtained a patent for impregnating lime and water with chlorine, and, in April 1799, a patent was taken out in his name for impregnating dry lime with chlorine. The process for producing bleaching-powder consists, at present, of three stages. 1. The formation of the hydrate of lime; 2. The evolution of chlorine; and, 3. The absorption of the gas by the lime. 1. In this country the lime usually employed is the Irish limestone, which is beautifully white and pure — constituting the chalk of Ireland. It is burned in lime-kilns, and then slaked with water. 2. The chlorine is disengaged from large stone stills by the action of hydrochloric acid upon black oxide of manganese, assisted by a steam heat, or by any of the methods already recommended for the production of chlorine. The retort is a stone box, double, so as to admit steam round it. The materials are introduced into the still by an aperture on the top, and the acid by another opening, supplied with a funnel. The chlorine is conducted by a lead tube, and enters at the top of the lime chambers. 3. These chambers consist of apartments of sandstone, cemented with a mixture of pitch, rosin, and gypsum, supplied with doors, which are rendered air-tight during the extrication of the gas, being built close up. The hydrate of lime is strewed over the floor of the chamber to the depth of three or four inches; the chlorine is allowed to remain in contact with it for four days. Some makers of bleaching-powder strew the powder upon shelves, in order to present a greater surface to the action of the chlorine. Good bleaching-powder should be perfectly white, and attract moisture but slowly in the air; it should be soluble in twenty parts of water, without leaving much

residue. The solution is alkaline. The nature of bleaching-powder is still a subject of dispute. The best supported view is that it is a compound of Ca Cl + CaO ClO, that is, of chloride of calcium and of hypochlorite of lime with some caustic lime.

Testing Bleaching-Powder. One of the most convenient methods of testing bleaching-powder is that of Dalton, depending upon the conversion of the protosulphate of iron into the persulphate, at the expense of the oxygen of water decomposed by the chlorine of the bleaching-powder. For this purpose, we take 4 atoms of good crystals of protosulphate of iron ($Fe\ OSO_3\ 7\ HO$), or 69·5 grs. previously well dried and pulverized, and dissolve them in two ounces of distilled water, with the addition of a few drops of SO_3 placed in a stoppered bottle. We then weigh out 50 grains of the specimen of bleaching-powder to be tried, and add it, in small portions at a time, to the copperas solution, shaking the mixture between each addition, and gently applying heat. As every atom of protoxide of iron requires half an atom of oxygen to convert it into the peroxide, this is equivalent to half an atom of chlorine in the bleaching-powder, or 2·25 grs. of Cl. When 4 atoms of the protoxide have been peroxidized, it is equivalent to 2 atoms of chlorine in the powder, or 9 grains by weight of Cl. The peroxidation of the solution is judged of by frequently taking out a drop with the end of a rod, placing it on a piece of white porcelain, or spotting it on blotting paper, and then adding a drop of a solution of red prussiate of potash. As soon as a blue precipitate of Prussian blue ceases to be formed, we infer that the whole of the protoxide, in the 69·5 grs. of sulphate of iron has been peroxidized. We then weigh the residue of the bleaching-powder. Suppose it amounts to 15 grs., then this amount, deducted from 50 grs., shows that 35 grs. of the bleaching-powder contained 9 grs. of chlorine. We have then the proportion, 35 : 100 :: 9 : 25·7 = the quantity of chlorine contained in 100 grains of the sample.

Carbonate of lime, calcareous spar, $CaO\ CO_2$ 6·25. *Chalk, limestone, marble, marl, oolite, travertine.* Primary form an obtuse rhomboid — 680 modifications of crystalline form have been described — all of *which* are referable to rhomboids, prisms, and pyramids. When the angle of the summit is replaced by three or six planes, resting on the primary planes or edges, so as to obliterate the primary faces of the crystal, 3-sided or 6-sided pyramids are produced. Lustre splendent and vitreous, hardness 3. Specific gravity 2·721. *Arragonite* is a dimorphous form of calcareous spar. Crystal right rhomboidal prism. Hardness 3·75, specific gravity 2·931. It has essentially the same composition as calcareous spar; but sometimes, however, contains carbonate of strontian in minute quantities.

Carbonate of lime may be obtained pure by precipitating chloride of calcium with carbonate of ammonia, washing and burning. It may be procured in a light form by washing it, and allowing it to dry spontaneously on the filter; 1 part of carbonate is soluble in 10,601 parts of cold and 8834 of boiling water, and in 65,246 parts of water containing alkaline salts in solution (Fresenius). It is soluble in water impregnated with CO_2; when heated to a high temperature, it loses its CO_2. Under pressure, when ignited, it melts and assumes the appearance of granular limestone (Hall), some CO_2 being evolved. Carbonate of lime enters very extensively into the constitution of the globe under the forms of primary limestone (Tyree marble, Parian marble), mountain or transition limestone under the coal, coal limestone and chalk.

Sulphate of lime, $CaO, SO_3\ 2HO$ — *gypsum, plaster of Paris, selenite, alabaster.* Crystal, right oblique prism. Hardness 2, specific gravity 2·31. This mineral occurs principally in the new red sandstone formation, and also in the tertiary formations round Paris. When heated to 225° it loses $1\frac{1}{2}$ atoms of water, the rest at 400°, and on being pounded and mixed with water, it again combines with water, and thus sets, and is useful in forming casts. This mineral occurs also destitute of water, crystallized in rectangular prisms. Specific gravity 2·899. Hardness 2·75 to 3. *Phosphate of lime, Bone earth, Guano earth*, $8CaO\ 3PO_5$ or $2(3CaO\ PO_5) + HO\ 2CaO\ PO_5 + 3HO$, obtained from calcined bones or guano, by dissolving in HCl, and precipitating the solution by NH_3. Is an excellent manure.

Estimation. — Lime is usually separated from its solution either in a neutral or alkaline state by oxalate of ammonia; the ignited precipitate is $CaOCO_2$, every $6\frac{1}{4}$ parts of which contain $3\frac{1}{2}$ of lime.

Magnesium. Mg 1·5.

Magnesium was discovered by Davy, in 1808, by exposing moistened magnesia to the action of galvanism in contact with mercury. Bussy showed, in 1828, that it might be obtained by passing the vapour of potassium over the chloride of magnesium, or by heating them in a dry state in a tube. White solid metal like silver, heavier than water, melts at no very high temperature, and volatilizes at a white heat.

Magnesia, oxide of magnesium, calcined magnesia, MgO 2·5. About 1700, *magnesia alba* was exposed for sale by a Roman canon. In 1707, Valentini found it in the lixivium from nitre, and in 1709, Slevogt observed it in the mother ley of nitre. In 1755, Dr. Black distinguished it from lime. Magnesia is found united with acids as a sulphate in Epsom springs, as a carbonate in magnesian limestone, as a silicate in serpentine, nephrite, meerschaum, hornblende, asbestus, talc. It is most conveniently

prepared by igniting the carbonate of magnesia, which is obtained in a natural state in Madras; but in this country is usually obtained from bittern or sea water, from which as much as possible of the common salt has been crystallized out. The bitter mother liquor contains muriate of magnesia, which is to be precipitated by means of an alkaline carbonate, and washed. When this carbonate is calcined, the result is pure magnesia. It requires a lower temperature to remove the CO_2 than lime. Magnesia is a soft white powder, with little taste, and no smell, specific gravity 2·3 (Kirwan), 3·2 (Karsten), 3·07 (Richter), converts vegetable blues to green. When calcined magnesia is pure, it dissolves entirely without effervescence in acids, and when a quantity of sal ammoniac is added to the solution, the magnesia is not precipitated by caustic ammonia. It is permanent at a red heat, but volatilizes at very elevated temperatures (Liebig). It is used in this form as a mild aperient and corrector of acidity.

Hydrate of magnesia, MgOHO 3·625. 1 part of magnesia dissolves in from 53 to 56,000 parts of hot and cold water, being equally soluble in both (Fresenius). The hydrate may be prepared by dissolving the sulphate of magnesia in water, adding caustic soda or potash; throwing the precipitate on a filter, washing it and drying it in a gentle heat. Hydrate of magnesia occurs in nature in the form of pearly scales, or crystallized in low 6-sided prisms, and at Hoboken, in New Jersey, in needles. Specific gravity 2·35; contains 68 per cent. of magnesia and 31 of water. It dissolves in acids without effervescence.

Salts of Magnesia. — Magnesia neutralises the acids, and forms salts, most of which are soluble in water, and crystallizable. They are decomposed by the carbonates of potash and soda, and also by caustic potash and soda. Ammonia precipitates them only partially in consequence of the formation of a double soluble salt of magnesia and ammonia. If a salt of ammonia be added to a solution of a magnesian salt, then an excess of caustic ammonia, on the addition of phosphate of soda, the ammonia phosphate of magnesia falls in granular crystals, which attach themselves to the sides of the glass, and if lines be drawn with a rod on the sides of the glass, the salt will be deposited in the course of those lines. —(Dr. Wollaston.) When a magnesian salt, tinged with some nitrate of cobalt, is fused before the blow-pipe, it assumes a flesh colour.

Chloride of Magnesium — Mg Cl 6 HO. 4-sided prisms, with nearly square bases, deliquescent in the air. It dissolves in half its weight of cold water, or one quarter its weight of boiling water, and twice its weight of alcohol of specific gravity ·817. Taste bitter. At 223° this salt begins to part with its acid, and at a red heat the acid is driven off, and magnesia remains.

Sulphate of Magnesia, Epsom salt, Bitter salt, Sal cathartic us amarus, English salt, Seidlitz salt. MgO SO_3 7 HO 15·375,

right prisms — with nearly square bases, the angles deviating from right angles, being 90° 30′ and 89° 30′. Specific gravity 1·66. Taste, intensely bitter. Grew described the salt in 1675, and in 1723 Brown described the process for obtaining it. It occurs in sea water and in springs, as at Epsom, Seidlitz, Saidschütz. It may be prepared from magnesian limestone, by digesting with dilute sulphuric acid until effervescence ceases, and then crystallizing out the sulphate of magnesia, after filtration. It may be freed from iron by boiling it with an excess of magnesia. Water at 60° dissolves its own weight of this salt. If pure, Epsom salt should give no precipitate with sulphohydret of ammonia — if it becomes black it is a proof of the presence of iron, which may be separated by calcining the salt, dissolving in water, and crystallizing. It may be made by dissolving magnesia alba in SO_3. Sulphate of magnesia is employed as an aperient, and as an antidote to salts of lead. It forms with sulphate of potash a double salt $MgOSO_3 KOSO_3 + 6HO$.

Carbonate of Magnesia, Mg O CO_2, as it occurs in nature, is destitute of water, but as prepared artificially it contains water. *Magnesite* is sometimes found amorphous; at other times in rhombohedral crystals, resembling carbonate of lime. When a salt of magnesia is boiled with carbonate of potash the precipitate diffused through water, and a current of CO_2 passed through it, crystals are deposited, consisting of MgO CO_2 3HO. By exposure to the air this salt loses water, and becomes Mg O CO_2 HO.

Magnesia alba of the shops is obtained by precipitating a soluble salt of magnesia with carbonate of soda or potash. — *Light* magnesia is obtained by boiling equal parts of sulphate or muriate of magnesia and carbonate of potash or soda in at least ten times their weight of water. — *Heavy* magnesia is the result of the previous experiment, when only half the amount of water indicated is used. Magnesia alba consists of 3 (Mg O CO_2) + MgO HO + 3 HO or, is a mixture of carbonate of magnesia with hydrate of magnesia. The exact solubility of this salt in water is not known; but when in solution it is sometimes used as a medicine. This is promoted by an additional quantity of carbonic acid, although there is no evidence of the existence of a bicarbonate. It reddens litmus.

Magnesia occurs in nature united to silica, as in *olivine* (MgO SiO), *Nephrite* (MgO $1\frac{1}{2}$SiO HO), *Picrosmine* (MgO 2SiO) *Magnesite* (MgO 3SiO 2HO), *Anthophyllite* 3 (MgO 2SiO) FeO 2SiO.

Estimation. — Magnesia is separated from its solutions by phosphate of soda and caustic ammonia, a large quantity of sal ammoniac being previously added to the solution. When ignited the precipitate is phosphate of magnesia, 7 grains containing $2\frac{1}{2}$ Mg O.

BASIC RADICALS.

Class III. Metals of the Earths Proper.

Aluminum.	Cerium.	Yttrium.
Glucinum.	Didymium.	Erbium.
Zirconium.	Lantanum.	Terbium.
Thorium.		

The earths proper are ten in number,—viz. *Alumina*, *Glucina*, *Zirconia*, *Thoria*, *Didymia*, *Lantana*, *Ceria*, *Yttria*, *Terbia*, *Erbia*. The only important earth is alumina, many of the others being imperfectly known. They are all precipitated white by NH_3, and also by soda; alumina and glucina, being soluble in that alkali. They are all precipitated by NH_3SH, not as sulphurets, but as oxides, SH being evolved. They are not precipitated by SH.

Aluminum.

Al. 1·75 obtained by heating chloride of aluminum in a platinum crucible with potassium, the lid of which is held down by a wire. The metal resembles in appearance platinum; less fusible than cast-iron; non-conductor of electricity; burns at a red-heat with great splendour, and is converted into alumina.

Alumina, Al_2O_3 6·5. *Argil*, *Clay*, *Oxide of Aluminum*, occurs nearly pure in corundum, crystallized in acute rhomboids, or 6-sided prisms: specific gravity 3·95. Alumina is obtained in a pure form from a solution of alum by precipitation, by means of caustic ammonia. It falls in the form of a thick jelly. This is thrown on a filter, and washed with hot water, till the liquor passing through is not precipitated by chloride of barium. When dry, it is a white powder, without taste and smell, but adhering strongly to the tongue, insoluble in water and alcohol, but soluble in caustic potash, and soda, and also slightly in caustic ammonia, when no ammoniacal salts are present in solution — specific gravity 4·2. It unites with acids, but constitutes a weak base. The salts are generally colourless and soluble in water, having a sweet and astringent taste; are not precipitated by prussiate of potash and tincture of nutgalls, by which they are distinguished from salts of Yttria and Glucina. — Alumina is supposed in some cases to act as an acid: as when dissolved by soda. Alumina, next to silica, is the principal constituent of soils.

Chloride of Aluminum, Al Cl, in a dry state, is made by heating to redness alumina with lampblack, placing the mixture in a porcelain tube, and passing chlorine over it heated. The chloride becomes of a pale green colour.

Sulphate of Alumina, $Al_2\ O_3\ 3\ S\ O_3\ 18\ H\ O$—41·75, made by dissolving alumina in sulphuric acid: an impure form of it is employed in manufactures prepared by acting on porcelain clay with the same acid.

Alum, Potash Sulphate of Alumina, $K\ O\ SO_3\ Al_2\ O_3\ 3\ S\ O_3\ 24\ H\ O$ — 59·5, may be formed by adding a solution of sulphate of potash to the preceding salt; but a more economical method is, to burn alum slate, which contains a quantity of bisulphuret of iron. By heating it, the sulphur unites with oxygen, and is converted into sulphuric acid. One of the atoms remains attached to the iron, and the other, on digestion in water, unites to the alumina ($Fe_3\ S_8$, $Al_2\ O_3$ and 21 oxygen from air become 3 ($Fe\ O\ S\ O_3$); and $Al_2\ O_3\ 3\ S\ O_3$). On the addition of sulphate of potash, or chloride of potassium, to this salt, in solution, alum crystallizes out in large octahedrons, characterised by the well-known peculiar astringent and sweet taste. Alum, in solution, reddens vegetable blues, dissolves in three-fourths its weight of hot water: 100 parts of cold water dissolve 14¾ of alum. Heat removes all the water and the greater part of the acid. *A pyrophorus* is produced by dissolving 6 parts of alum and 2 of sugar in water; evaporating to dryness; igniting the mixture in a coarse porcelain retort or blacking-bottle, and stopping the mouth, after the disappearance of a blue flame, with a clay or chalk stopper. When cool, if the stopper be taken out cautiously, and the black powder shaken out, it catches fire and burns; the sulphuret of potassium oxidizing.

Alum-baskets are made by suspending baskets of woollen thread in a saturated solution of alum: the alum crystallizes very beautifully on the thread. In the same way the alum may be made to assume any particular form.

Earthenware, Porcelain, Pottery, Stone-ware, China, Crockery, are all names given to different varieties of tea-cups and dinner-sets, &c., which consist essentially of silica and alumina. The raw materials from which the earthenware or china of this country is made consist of decomposing granite, clay derived from the decomposition of this rock, termed China-clay, and flints. These ingredients, properly prepared and mixed together in the requisite proportions, to form an adhesive compound, are shaped by mechanical means into the forms required, and are then burned in a kiln. The common white earthenware contains 68 per cent. of silicic acid, 29 of alumina, and a little iron. English transparent china contains, in addition to these ingredients, about 15 per cent. of phosphate of lime derived from

bones. *Brown salt glazed* ware, of which gallon jars, blacking-bottles, &c., are made, receives the gloss on its surface by having common salt thrown over it when at a strong heat. The soda of the salt unites with the silica of the ware, forming a glass, and hydrochloric acid is set free. The glazes used in the finer kinds of ware contain, generally, borax, which readily fuses when exposed to heat. The colours painted on porcelain are laid on with the hand and brush, and are glazed over, so that the colours can never be removed by any external application.

Acetate of Alumina, a salt much used in dyeing, is obtained by adding acetate of lead to a solution of alum; sulphate of lead falls, and acetate of alumina remains in solution. When boiled, half of its alumina falls in the state of subacetate, but dissolves on cooling.

Tests. — Alumina is distinguished from the other earths by its solubility in potash and soda, and insolubility in carbonate of ammonia, glucina being soluble in that alkali. It may be separated from its solution quantitatively by NH_3, or NH_3SH.

Glucinum, G 3·25 (Vauquelin, 1798) and *Glucina* G_2O_2 9·5, is found in beryl, united with silica. The pounded mineral is fused with carbonate of soda or bisulphate of potash; the fused mass dissolves in hydrochloric acid and water; the silica is separated in the usual way, and filtered; the glucina is precipitated by NH_3, washed and dissolved by a strong solution of carbonate of ammonia, and thrown down by boiling. A white powder, tasteless, insoluble in HO, forming sweet-tasted salts with acids.

Zirconium, Zr 4·25. (Klaproth, 1789), Zirconia, Zr_2O_3 11·5, procured from the zircon, by fusion with carbonate of soda: when a neutral salt of this earth is treated with a saturated solution of sulphate of potash, the zirconia falls as a sub-salt. When this earth is heated it is scarcely soluble in acids. Sp. grav. 4·3. *Norium* is said to exist in some zircons.

Thorium, Th 7·5. (Berzelius, 1828) Thorina ThO 8·5(?), white earth, obtained from thorite by digesting the mineral in HCl, evaporating, dissolving in weak acid; passing SH through the solution to remove lead and tin, and throwing down by NH_3. The precipitate is washed and dissolved in SO_3; the liquor being evaporated a sulphate of thorina is formed: when heated it is decomposed, and when washed the pure earth remains. It is insoluble in caustic alkalies: it is precipitated by yellow prussiate. It is distinguished from zirconia by its insolubility when precipitated from a hot solution of sulphate of potash, and from yttrium by its forming with sulphate of potash a double salt insoluble in a cold saturated solution of sulphate of potash.

Cerium, *Didymium*, *Lantanum*. These substances have not been properly distinguished, in consequence of the difficulty of separating them from each other. They occur in *Cerite* and *Allanite*. Ceria may be separated from Lantana by igniting the mixture of these two bodies and digesting the ignited mass in weak NO_5, which has the property of dissolving the lantana and leaving the ceria. The methods recommended in books for separating ceria refer to all these three metals, which usually occur together, and have never been completely separated.

Yttrium Y 4. (Gadolin, 1794.) This substance is always accompanied with erbium and terbium, so that no accurate description of its characters has been published. When to a solution of a salt of yttrium, as usually prepared from yttria, is added gradually a solution of an alkali; at first there falls a precipitate, which is rendered yellow or orange by ignition, consisting of oxide of erbium with oxide of terbium and yttrium: the second precipitate is paler yellow on ignition, consisting principally of oxide of terbium: the third precipitate remains quite white on ignition, and is yttria. The salts of erbium are red — of terbium pale red — of yttrium colourless.

BASIC RADICALS.

Class IV. Difficultly Fusible Metals.

Iron (cast) - -	2786°	Cobalt - -	above 2786°
Manganese, Nickel -	above 2786°	Copper - -	1996°
		Silver - -	1830°

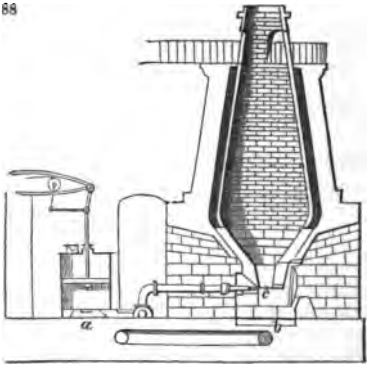
Iron. Fe 3·5. (Ferrum, Mars.)

Characters. — Iron is a grayish white metal, crystallising in octahedrons, harder than most metals, particularly when combined with carbon in the form of steel; specific gravity 7·84; attracted by the magnet, malleable at all temperatures, is capable of being drawn out into fine wires (ductile); melting point 2786°. Iron never exists in nature in a free state, but is usually united with oxygen, as in hæmatite ($Fe_2 O_3 2HO$), magnetic iron ore ($FeO\ Fe_2 O_3$), and clay ironstone, or carbonate of the protoxide of iron ($FeO\ CO_2$).

Process. — In Scotland iron is made principally from the carbonate or clay ironstone which is found abundantly in the neighbourhood of Glasgow, associated with the coal beds. The stages of the process for its reduction are four: 1. decarbonating, roasting, or calcining; 2. deoxidising or smelting; 3. decarbonising or refining; 4. further decarbonising or puddling.

1. The *calcining* is performed by piling the ironstone in a heap seven or eight feet high, thirty or forty feet in length, and fifteen or more in breadth, and setting fire to it. In consequence of the *black band*, or best ore, being intimately intermixed with coal, it burns of itself, and requires no fuel. The carbonic acid is thus expelled, and the iron remains united with oxygen. 2. The *smelting*, or deoxidating process, is conducted in the blast furnace (fig. 88.), a tall building, fifty or sixty feet high, familiarly known from its illuminating power at night. The ore is thrown with an equal weight of coal, and one-fifth of limestone, all finely broken, into the blast furnace, and exposed to an intense heat, by means of a current of hot air blown in at the bottom. The carbon of the coal removes the oxygen from the ore in the form of carbonic acid, the limestone unites with the silica and impurities in the ore, and forms a slag, which swims on the surface of the metallic iron at the bottom of the furnace. In the course of twenty-four

hours, the iron is quite reduced, and is drawn off by taking out a *plug* or *tap* at the bottom of the furnace. It is allowed to



a. blowing machine. *b.* blast furnace. *c.* hearth.

run into a bed of sand, which is formed into straight channels and furrows running at right angles; the former are termed the *sow*, the latter the *pigs*, and hence the origin of the term *pig iron*, by which iron *cast* in these sandy channels is known. Cast iron has three qualities. No. 1. is the most valuable, as it contains the smallest amount of charcoal. No. 2. contains carbon only in the centre. No. 3. contains most carbon, and is therefore inferior. (3.) When hammered iron is required it is made from cast iron by the process of *decarbonising* or *refining*. The cast iron, No. 1., is placed in a refining furnace along with coke, and heated intensely by means of a strong blast of air in contact with the atmosphere; the iron by this process becomes purer and white; 4th. it is still further *decarbonised* or *puddled* by being introduced into a reverberatory furnace, powerfully heated and stirred constantly for two or three hours. It is then made into balls, hammered, and drawn between rollers, while still hot, into *mill bar iron*, *railway bars*, &c.

Steel is made from bar iron, by placing it, surrounded by finely pounded charcoal, in a furnace covered up with sand, and heated intensely for a week or ten days. The carbon unites with the iron, and forms a carburet of iron or steel. When the steel bars are broken and frequently *welded* or hammered together, they are termed German or *shear* steel, because they were originally thus prepared for making *shears* to dress woollen cloth. *Cast steel* is obtained by breaking up the bars, fusing them in a crucible, and pouring the melted steel into moulds.

Steel is whiter than iron; texture granular, fracture whitish-grey; more brittle than iron. Its hardness is increased by heating and plunging into water. A drop of nitric acid leaves on steel a black spot (carbon); on iron a whitish-green stain (oxide). *Case hardening* consists in converting the surface of iron into steel by heating it with charcoal for a short time. Keys and gunlocks are thus treated. *Tempered* steel is required for knives and other cutlery instruments. This is effected by heating the articles in oil raised to the proper temperature. Penknives and razors require a heat of 460°, and have a straw-yellow colour; watch-springs are made deep blue at 580°. These colours are obviously produced by a partial union with oxygen of the air, for when heated in hydrogen no change of colour occurs.

Protoxide of Iron, FeO 4·5, may be obtained as a hydrate; that is, in union with water, by precipitating a solution of well crystallized *green vitriol* or *copperas* (FeO SO_3 7 HO), by caustic ammonia, or potash, or soda. It is first thrown down white and then becomes green: by exposure to the air it absorbs oxygen, and is converted into the sesquioxide or brown oxide (Fe_2 O_3). The dry protoxide may be obtained from the red oxide by passing hydrogen over it at a temperature not sufficient to reduce it. It has then a deep black colour, and burns with great splendour when heated in contact with air.

Sesquioxide, peroxide, red oxide, deutoxide, rust, $FeO_{1\frac{1}{2}}$ or Fe_2 O_3 10·, may be formed from sulphate of iron or green vitriol, by dissolving the salt in water, adding nitric acid and heat until the black colour, which at first shows itself, is changed into a bright yellow. On the addition of caustic ammonia to the sulphate of the peroxide of iron, the peroxide falls in the form of a brownish-red flocky precipitate. It may also be prepared by dissolving iron in nitric acid, and precipitating by alkalies or alkaline carbonates. When dried it is a fine brownish-red powder, insoluble in water, tasteless, soluble in hydrochloric acid with the evolution of chlorine. (Fe_2 O_3 + 3H Cl becoming Fe_2 Cl_3 3HO and Cl.) When freshly precipitated it constitutes the antidote to arsenious acid, and when administered is to be diffused through water by means of a knife or spoon, and drank freely. It is used also as a tonic in nervous diseases. Peroxide of iron occurs in nature abundantly, in the form of hæmatite, an iron ore. (Fe_2 O_3 2 HO.) *Rust* is formed when iron is exposed to the atmosphere. It consists of the red oxide mixed with some carbonate of the protoxide of iron.

Magnetic oxide, Loadstone, Black oxide, Ferroso-ferric oxide, $FeO_{1\frac{1}{3}}$ 4·833 or FeO Fe_2O_3 14·5, occurs abundantly in nature, as magnetic iron ore, in octahedral crystals. It occurs in Sweden, and forms the iron from which the best steel is made.

Ferric acid, $Fe\ O_3$ 6·5, is obtained by passing a current of chlorine gas through a strong solution of potash, in which the sesquioxide of iron is suspended. When the mixture is filtered it possesses a fine amethyst colour—ferrate of potash. *Protochloride of Iron*, Fe Cl 8, a gray, variegated, metallic, solid, in plates, melting at a red heat; soluble in water obtained by dissolving iron in hydrochloric acid, and igniting the residue in a tube away from the air. *Sesquichloride*, $Fe_2\ Cl_3$ 20·5, produced when iron wire is burned in chlorine gas. A solution of this salt in alcohol is used in medicine as a tonic, termed Tinctura ferri Sesquichloridi, *Iodide of Iron*. (See Iodide of potassium.) *Sulphuret of Iron*, Fe S 5·5, is much used in the preparation of sulphohydric acid. It is made by heating an iron bar to redness, and bringing it in contact with a roll of sulphur, over water; sulphuret of iron is formed and drops into the water. It is essential that the iron be intensely hot. It may also be formed, but of inferior purity, by heating sulphur and iron filings in a clay crucible.

Sulphate of iron, Green vitriol, Copperas, Fe O SO_3 7 HO, 17·375, may be formed by dissolving iron in sulphuric acid, with the addition of water. In commerce it is prepared on a large scale in the alum manufacture, the sulphate of iron being crystallized out from the sulphate of alumina. Copperas crystallizes in green rhomboidal prisms. When heated it loses water and acid, and leaves a red powder (*colcothar of vitriol*), which is an impure peroxide. *Persulphate of iron*, $Fe_2\ O_3\ 3\ SO_3$ 25·, formed by oxidating the protosulphate by means of nitric acid, as already described. Green vitriol is used as a tonic in nervous diseases, and where the blood is supposed to be deficient in iron, as in chlorosis, anæmia. *Potash tartrate of iron*, obtained by boiling the sesquioxide with cream of tartar (bitartrate of potash), and evaporating. Used as a tonic in medicine.

Gun barrels are browned by sponging with the following mixture: 3 oz. alcohol, 3 oz. tincture of iron, 1 oz. corrosive sublimate, 3 oz. of nitric ether, 2 oz. sulphate of copper, 1½ oz. nitric acid; and after drying, rubbing with a scratch card or brush.

Estimation of iron.—Iron is always estimated in the form of sesquioxide; every five parts being equivalent to 3½ of metallic iron. It is usually precipitated from its solution by caustic ammonia.

Manganese. Mn 3·5. (Kaim, 1770.)

Character.—A gray metal, texture granular, hard and brittle, pulverizeable. Specific gravity 8·013, not magnetic, oxidizes readily in the air. *Process.*—It is prepared from the oxides of manganese, by forming them or the tartrate into a paste with oil, placing it in a clay crucible covered with charcoal powder, and exposing it to a white heat for two hours.

Protoxide of manganese, Mn O 4·5, formed, by heating the carbonate of manganese in hydrogen gas; a greenish powder, which catches fire when heated in the air, and burns into a brown powder (Mn $O1\frac{1}{3}$). This oxide unites with acids, and forms an extensive series of salts, generally characterised by a flesh colour. *Sesquioxide*, Mn $O1\frac{1}{2}$ or $Mn_2 O_3$ 10·, *brown oxide*, occurs in nature in the form of iron grey crystals, having a brown colour when pounded. *Red oxide*, $Mn_3 O_4$ or Mn O, $Mn_2 O_3$, or Mn O $1\frac{1}{3}$ 14·5, obtained, when any of the oxides are ignited; and it occurs native. *Deutoxide, binoxide, black oxide, brown stone*, Mn O_2 5·5 occurs native in needles and in masses in Devonshire and on the Rhine. When pounded it forms a black powder. When heated strongly it loses 12 per cent. of its weight in the form of oxygen; and hence this is the most economical process for preparing this gas. It is used also extensively for the manufacture of bleaching powder. Hence it is important to know the amount of oxygen which it is capable of parting with.

Testing value of black oxide.—Into a light glass flask, weighing a few hundred grains, fig. 70. are to be introduced about 600 grains of water, 150 of sulphuric acid, and 75 grains of oxalic acid; 50 grains of the sample of black oxide of manganese, finely pounded, are weighed out in a small tube, weighing about 30 or 40 grains, which is to be suspended in the flask by means of a thread, retained in its place by a cork, through which passes a small tube filled with chloride of calcium, the tube being closed at each end by a piece of cotton. The whole is then weighed accurately; the tube containing the oxide is then lowered into the mixture in the flask. An effervescence takes place by the extrication of carbonic acid (CO_2 CO, Mn O_2, SO_3 becoming 2 CO_2 Mn O SO_3). Every atom of black oxide (Mn O_2), or 5·5 grs., will give rise to the extrication of 2 atoms of carbonic acid (2 CO_2) or 5·5 grains. When the action has ceased, which is denoted by the brown colour of the residue in the flask, the apparatus is again weighed. The loss of weight indicates the amount of CO_2 extricated. But as the weight of 2 atoms of carbonic acid (5·5) is equal to that of one atom of black oxide (5·5), it is obvious that the loss of weight is exactly equal to the amount of black oxide present in the sample. — (*Dr. T. Thomson.*)

Weight of black oxide	-	50 grs.
Weight of flask and materials		1025
		1075
Weight after effervescence		1041
Loss of carbonic acid	-	34 grs. = 68 per cent. Mn O_2.

Manganic acid, Mn O_3 6·5, formed by fusing equal parts of black oxide and saltpetre or caustic potash; a black mass results, which becomes in water green, blue, purple, and reddish brown, turning into the red oxide. This substance is termed the chameleon mineral, in consequence of the changes of colour depending on the absorption of oxygen. *Hypermanganic acid*, Mn_2 O_7 14·, prepared by heating 3¼ parts chlorate of potash, 4 parts black oxide of manganese, and 5 parts dry caustic potash dissolved in water. (*Gregory*). The whole is evaporated to dryness in a porcelain crucible, and exposed to a low red heat, but not fused. The powder is taken out, digested in water, the clear liquor poured off and evaporated; black crystals of hypermanganate of potash crystallize out. The solution of these crystals in water is finely red, but cannot be concentrated, in consequence of the tendency of the acid to give out oxygen. When passed through filtering paper it decomposes.

Chloride of manganese, Mn Cl 4 HO, flesh-coloured plates and prisms, obtained, in the preparation of chlorine, by the action of hydrochloric acid on black oxide of manganese.

Perchloride, Mn_2Cl_5, greenish brown liquid, formed by acidulating the chameleon mineral with sulphuric acid, evaporating, and adding sulphuric acid and common salt, and distilling.

Sulphate of Manganese, MnO SO_3 7 HO, formed by dissolving carbonate of manganese in sulphuric acid, or in the preparation of oxygen by the action of sulphuric acid on black oxide of manganese. The liquor is to be neutralized by boiling with a sufficient quantity of black oxide, when the iron forming the impurity is precipitated: the crystals are flesh-coloured prisms, soluble in water, and acting as an aperient medicine when taken internally.

Estimation. — Manganese is separated from its solutions by carbonate of soda, or NH_3 SH, and from iron by benzoate, or succinate of ammonia, which precipitates the iron, but not the manganese, in neutral solutions.

Nickel. Nk 3·75. (Cronstedt, 1751.)

Characters. — Occurs in meteoric stones, chrysoprase, and in union with arsenic. The metal is white, ductile, and malleable. Specific gravity 9·; not magnetic (*Chenevix*). Fuses at a very high temperature (about 3000°). Decomposes water at a red heat. It enters into the composition of what is termed German silver and British plate. It is separated from its ore by fusing with nitre and carbonate of potash: the arsenic acid unites with the potash when nickel is oxidized, and remains undissolved when water is added. The oxide is then purified from cobalt and iron, and fused with charcoal. *Prot-*

oxide, Nk O 4·75, dark-greenish grey powder, formed by heating the carbonate, nitrate, or oxalate, forms green salts with acids. The alkalies precipitate it apple green, ammonia redissolving it, and forming a blue solution. *Peroxide*, $Nk_2 O_3$ 10·5, black powder, formed by passing chlorine through water, in which the hydrate of the protoxide is diffused. *Chloride of Nickel*, Nk Cl 8·25, obtained in green crystals by dissolving the metal in H Cl, and crystallizing. *Sulphate of Nickel*, Nk O SO_3 7 HO, green prisms, in form resembling Epsom salts.

COBALT. Co 3·75. (Brandt, 1733.)

Characters. — A steel-gray, hard, brittle, metal, of specific gravity 8·5, not magnetic (*Chenevix*, *Faraday*). Melting point about that of cast-iron.

Process. — It is obtained from arseniet of cobalt by the same process as that for nickel. After the separation of the arsenic, as already described, the insoluble oxide, consisting, it may be, of nickel, cobalt, and iron, is dissolved in an excess of oxalic acid, which dissolves the iron, and leaves the oxalates of cobalt and nickel undissolved. The iron is separated by filtration. The oxalate of cobalt is dissolved by the addition of ammonia, while the oxalate of nickel remains undissolved. Caustic potash precipitates the peroxide of cobalt, which may be reduced to the metallic state by a current of hydrogen.

Protoxide, CoO 4·75, an olive-green powder, becoming brown in the air, obtained by heating the carbonate. Cobalt does not unite with oxygen at common temperatures, but at a red heat it oxidizes, and at a white heat burns with a red flame, and decomposes water at a red heat. When heated with borax, before the blow-pipe, it gives a blue bead. It is precipitated from its solution blue by the alkalies; ammonia redissolves the precipitate. Alkaline carbonates form a pink precipitate. S H does not precipitate it; but sulphohydret of ammonia forms a black sulphuret. —*Brown oxide*, Co O $Co_2 O_3$ 15·25 obtained by heating the protoxide.

Sesquioxide, $Co_2 O_3$ 10·5, black powder, obtained by heating the protoxide with bleaching-powder, or chlorine gas. The hydrate of the protoxide is suspended in water, and the gas passed through the mixture. Cobalt occurs in commerce in the form of a blue powder. *Smalts*, made by fusing cobalt ore with sand and potash. The light *Cobalt blue*, or *Thenard's blue*, is formed by precipitating a mixture of a solution of alum and cobalt salt by an alkali and ignition. *Rinman's green* is produced by substituting zinc for alum in the preceding experiment.

Chloride of Cobalt, Co Cl 8·25, *sympathetic ink salt*. The solution is formed by acting on cobalt, or the oxide, by means of hydrochloric acid. It is a pink solution, and when concentrated,

blue. If we write upon paper with the pink solution, the letters are invisible; but if heated, so as to drive off the water, the letters are blue: hence it has been termed *secret* or *sympathetic* ink. Many other inks may be formed at one time invisible, and which may be rendered visible by chemical means. If we write, for example, on paper with a solution of chloride of iron, allow it to dry, and then brush the paper over with a solution of yellow prussiate of potash, we shall have a Prussian-blue ink impression, which, however, is soluble in ammonia: a writing made with the colourless acetate of lead becomes black, when brushed over with sulphohydret of ammonia. *Sulphate of cobalt*, $CoOSO_3$ 7 HO, in red oblique rhombs, obtained by dissolving the protoxide in SO_3, is homomorphous with copperas.

Copper. Cu 4. (Cuprum.)

Characters. — Bright brownish red metal with a fine lustre, found in nature crystallized in cubes, known to the ancients.

Process. — Copper is found native in Anglesea, &c. The common ore is, however, copper pyrites (FeS CuS), or yellow copper ore, from which the copper is reduced by driving off the sulphur by roasting, and then fused till the impurities separate. Napier's new process consists, 1. in fusing the ores, and separating a certain amount of slag; 2. fusing with salt, soda ash, lime and coal for half an hour; 3. calcination for twenty-four hours at a high temperature without fusing, to separate sulphur; 4. fusing with sand and coal, to form a silicate of iron as alloy, the copper separating in the metallic state. Ductile, malleable. Specific gravity when fused 8·78. Melting point 1996°. When strongly heated it communicates a green colour to flame; does not decompose water; does not dissolve in dilute sulphuric acid, but is very soluble in nitric acid.

Protoxide, CuO 5, black powder, formed by heating copper in the air, or by igniting the nitrate. When copper is exposed to a moist air it becomes incrusted with a *green coating*, often called *verdigris*, which is a hydrate of the carbonate of the protoxide of copper. Copper salts are poisonous; vegetable acids dissolve copper in the cold state and not in the hot state. Sauces containing vinegar, preserved fruits or jellies, should not be allowed to remain in contact in the cold state with German silver spoons (which consist of copper, nickel, and zinc), or copper stew-pans. Water containing common salt also dissolves copper. The protoxide colours glass green. The protoxide salts are blue or green when united with water, but white when anhydrous—poisonous. The antidote is sugar or white of egg: a plate of zinc, lead, or iron precipitates copper from its solutions. A knife, therefore, thrust into a copper salt speedily becomes yellow, affording a

distinguishing test for the metal. The best test is yellow prussiate of potash, which gives a brown precipitate when the metal is present even in very minute quantity.

Dinoxide, suboxide, red oxide, Cu_2O 9, native in octahedrons. It may be prepared by boiling a solution of sulphate of copper with starch or sugar, and caustic potash or soda; the red oxide subsides, or it is formed by fusing chloride of copper with carbonate of soda, or by heating protoxide with copper filings. Specific gravity 6·. Absorbs oxygen at a red heat, and becomes black oxide. Dilute acids convert it into metallic copper, and a salt of the protoxide; dissolves in ammonia; colours glass red.

Cupric acid, $Cu_2\ O_3$. — Dissolve 20 grains of black oxide in 70 grains nitric acid, of specific gravity 1·35. Then 50 grains fresh hydrate of lime are mixed with one pound solution of bleaching powder, specific gravity 1·06, and added to the solution of copper. A precipitate of a purplish black gradually subsides, which is washed with cold lime water. It is nearly black, but when placed in a thin layer on glass it is rose. (*Crum.*)

Nitret, Cu_6 N, a green powder, formed by passing dry ammonia over protoxide, turning at 570°, into nitrogen and copper. *Chlorides.* — There are two chlorides; the dichloride, a brown powder, Cu_2 Cl, formed by heating corrosive sublimate (Hg Cl) with copper; and the chloride, Cu Cl, green needles, obtained by dissolving copper in hydrochloric acid: this salt above 400° is converted into dichloride by losing half its chlorine.

Disulphuret, Cu_2 S, *copper glance,* a rich ore of copper found in Cornwall and South Australia. Copper unites with various metals, forming alloys. *Brass* consists of 3 parts of copper and 1 of zinc, and sometimes of 4 and 5 parts of copper to one of zinc. It is more fusible than copper; ductile; *pinchbeck* or *similor* consists of equal parts of the two metals, and possesses a golden colour: hence the name. *Bronze,* and the metal of cannon consist of 9 parts of tin and 91 of copper. The strength of bronze of this composition is to malleable iron as 1 to 2. *Bell metal* is also formed of copper and tin in different proportions; but a common proportion is 3 copper to 1 tin. *Mirrors* of telescopes consist of 2 copper to 1 tin. *Tinned pans* are copper pans covered with a layer of tin in the inside, to prevent the contents from acting on the copper. The copper pan is first rubbed over with salammoniac, heated; pitch is thrown into it, and a piece of tin rubbed over the copper surface.

China silver or *tutenag* consists of copper, zinc, and nickel. The same substances enter into the composition of Britannia metal and German silver. Spoons and forks of this description should not remain in contact with acid, sauces, or pickles.

Carbonate of copper, Cu O CO_2, blue and green, according to the quantity of water present, occurs in nature, and admits of

a fine polish, when it is known as *malachite*. *Nitrate of copper*, $CuO\ NO_5$, 3HO in prisms, or with 6HO in rhomboids, is obtained by dissolving metallic copper in nitric acid. When ignited, black oxide of copper remains. When moistened and rolled up in tinfoil, heat and light are given out, and peroxide of tin formed. *Sulphate of copper*, $CuO\ SO_3$ 5HO, blue doubly-oblique prisms, obtained by dissolving copper in SO_3, and crystallizing. It is used as an emetic in cases of poisoning, and as a caustic for sores under the name of *bluestone*. *Acetate* of *copper*, or *verdigris*, one of the cheapest salts of copper, formed by acting on copper with cloth dipped in vinegar, is used for preparing Scheele's green by mixture with arsenious acid.

Estimation. — Copper is usually separated as oxide by boiling with caustic soda or potash.

SILVER. Ag (Argentum) 13·5.

FINE white metal, softer than copper, harder than gold, crystallizes in octahedrons. Specific gravity 10·474; very malleable and ductile; 1 grain may be drawn out 400 feet; melts when completely red hot, or at 1830°.

Reduction. Silver is separated from lead when it occurs in the ores of that metal by oxidation, as stated under lead, when the ore occurs in the metallic state. It is treated with mercury, and the amalgam distilled; the mercury passes over and leaves the silver. Pure silver is obtained by dissolving silver in nitric acid, precipitating by hydrochloric acid, and fusing the washed chloride with twice its weight of carbonate of potash mixed with some nitre and pounded rosin in a clay crucible. The silver collects in a button at the bottom. Silver is separated from gold by dissolving the mixture in SO_3. The gold remains as in Chinese silver.

Oxide, AgO 14·5, grayish powder, obtained by precipitating nitrate of silver by caustic soda. Specific gravity 7·143. It combines with ammonia, forming an explosive compound, and is dissolved by an excess. The oxide does not form a hydrate. When the salts of this oxide in solution are mixed with mercury in a glass vessel, the silver is deposited in the form of a tree, called the *Tree* of *Diana* (Arbor Dianæ). The experiment may be made by dissolving 15 grains of nitrate of silver in half a wine glass-full of water, adding a few globules of mercury, and allowing the glass to stand at rest for some hours. The *permanent ink*, commonly sold for marking linen, contains in one bottle caustic soda or carbonate of soda, and in the other a solution of nitrate of silver. The spot to be marked is first moistened with soda, dried, and then written on with a pen dipped in the silver solution. The oxide is precipitated. The

salts of the oxide of silver are colourless, have a metallic taste, and are poisonous; the antidote being common salt. Copper, zinc, and mercury precipitate silver from its solutions. Ammonia redissolves the oxide when precipitated. *Dinoxide*, Ag_2O. The oxide of silver contained in citrate of silver loses only half its oxygen under the action of hydrogen gas, a suboxide being formed which forms a dark brown solution. *Peroxide* is deposited on the positive pole of a galvanic battery, in a solution of nitrate of silver in needles.

Chloride of Silver, Ag Cl, 18, *Horn Silver*, *Luna Cornea*, obtained by precipitating a solution of lunar caustic ($AgO\ NO_5$) with H Cl, or common salt. A white curdy precipitate; when moist, insoluble in nitric acid; when dry becoming purple and black: melts at 500°, and forms a horny mass, soluble in ammonia; crystallizes in octahedrons. When moist it may be converted into oxide by boiling with caustic soda and the addition of a little pounded rosin. The silver may be reduced by boiling the chloride in an iron pot with water. Specific gravity 5·55. *Iodide of Silver*, Ag I 29·25. Yellow powder, formed by dropping iodide of potassium into nitrate of silver. *Cyanide*, Ag Cy 16·75, white curdy precipitate, resembling the chloride, but distinguished from it by its solubility when boiled with nitric acid. This is used for procuring hydrocyanic acid in medicine. *Trisphosphate of Silver*, $3AgO\ PO_5$, yellow powder, obtained by precipitating nitrate of silver by the common phosphate of soda. *Diphosphate or Pyrophosphate*, $2AgO\ PO_5$, white powder, from the mixture of ignited phosphate of soda with a soluble salt of silver. *Nitrate of Silver*, *Lunar Caustic*, *Lapis Infernalis*, $AgO\ NO_5$ 21·25 in plates, obtained by dissolving pure silver in NO_5, and evaporating cautiously to drive off excess of acid. Used as a reagent and caustic. For the latter purpose it is fused and poured into tubes, where it solidifies. When free from organic matter it retains its colour, but if it has touched paper it becomes dark coloured. When heated it is partially converted into nitrite.

Alloys of Silver. — *English* silver coin contains copper; the quantity in a shilling, which weighs 87·2727 grains, is 6·5455 grains of alloy; or, in 12 ounces of standard silver, the copper amounts to 18 dwt., or 1 copper to 12⅔ silver; 1 lb. Troy yielding 66 shillings. *French* silver coin consists of 1 copper, 10 silver; *Dutch*, 1 copper to 11½ silver; *Russian*, 1 to 3¾; *Hamburg*, equal parts.

Estimation. Silver is always *estimated* in the form of *chloride* of silver; every 18 parts of which contain 13½ of metallic silver. It is best to precipitate silver by common salt, as the chloride is somewhat soluble in HCl.

BASIC RADICALS.

Class V. Easily Fusible Metals.

	Fusing points.		Fusing points.
Zinc -	- 680°	Tin - -	- 442°
Cadmium	- 442°	Bismuth -	- 497°
Lead -	- 606°	Mercury -	- -39°

These metals melt below a red heat. They are all precipitated in the metallic state from their solutions by zinc; and the others, by those above them, in the order in which they stand.

Zinc. Zn 4·125.

Characters. — Brilliant blueish white metal, rather soft, tinging the fingers black. Specific gravity when melted 7·; when hammered 7·81; melts at 680°, and distils at a white heat. At 400° it can be pounded. When cooled slowly it crystallizes in 4-sided prisms. It is found in nature in the state of *blende*, *Black jack* or *sulphuret* (Zn S), and as *calamine* or carbonate of Zinc (Zn O CO_2).

Process. — The metal is reduced by heating the ore along with small coal, in clay pots or crucibles. The metal drops through a hole in the bottom of each pot, by an iron tube, into a vessel of water. It is used for roofs, for milk dishes, chimney pots, &c. *Oxide*, Zn O 5·125. Zinc tarnishes in the air by uniting with a small portion of oxygen. Water is decomposed by the hot metal. When zinc is strongly heated in an open clay crucible it takes fire, burns with a white flame, and gives out abundant white flocks of oxide (*Philosophic wool*). It may also be prepared by precipitating any of the salts of zinc, as the sulphate, by an alkaline carbonate, washing and igniting the white carbonate; oxide of zinc remains, which is yellow when hot, white when cold. It is tasteless, soluble in ammonia and caustic alkalies, and can thus be separated from iron.

Chloride of zinc, Zn Cl 8·625, gray, solid, deliquescent; formed by dissolving zinc in hydrochloric acid, and igniting gently. It may be sublimed, when it crystallizes in needles. It is used as a caustic, also to preserve wood and cordage, and as a disinfecting agent.

Sulphate of zinc, Zn O SO_3 7 HO, prisms obtained in the preparation of hydrogen by acting on zinc with dilute sulphuric acid; used in the proportion of 1, 2, or 3 grains to an ounce of water, as an eyewater, in inflammation: it acts also as an emetic. It forms with sulphate of potash a double salt; the potash salt replacing one atom of water, Zn O SO_3, KO SO_3 6 HO. Magnesia, manganese, &c. form similar double salts.

Carbonate of zinc, Zn O CO_2, *Zinc spar*, *Calamine*, the common ore of zinc, a yellowish solid. The precipitated carbonate consists of a mixture of carbonate and hydrate of the oxide. (2 Zn O CO_2, 3 Zn O HO.)

A plate of zinc precipitates lead from its solution. *Galvanised iron* is obtained by plunging iron into melted zinc. An alloy is formed on the surface, which prevents oxidation. Zinc is usually estimated by boiling with carbonate of soda. To separate it from nickel it is necessary to precipitate both metals by an alkaline carbonate, to dissolve the carbonate in acetic acid, and pass a current of sulphuretted hydrogen through the solution, Zn S is precipitated, while the nickel remains in solution.

Cadmium. Cd. 7.

Characters.—A whiter metal than zinc, with which it is generally associated. Fracture hackly, crystallizes on cooling in octahedrons, soft and easily cut, ductile: specific gravity 8·7, melting point 442°, rising into vapour above 600°. *Process.* — It may be separated from zinc by caustic soda, in which it is insoluble, or by carbonate of ammonia, which, in excess, dissolves zinc, but not cadmium; the oxide thus obtained may be reduced in the same way as zinc. A plate of zinc precipitates metallic cadmium. *Oxide*, Cd O8. Cadmium burns in the air like zinc, forming a brownish yellow smoke of oxide. The oxide may be obtained pure by precipitation from its salts by soda or carbonates. It is a yellow powder. The *Sulphuret* is yellow, and acts as a paint while that of zinc is white. The two metals may thus be easily distinguished. The sulphuret (Cd S) occurs native in the form of a beautiful mineral—*Greenockite*. The *Chloride* is a rectangular prism.

Lead. Pb 13 (Plumbum).

Characters. — A blueish white metal, staining the fingers and paper, and cutting soft, with a fine lustre; specific gravity 11·35, not increased by hammering; very malleable, and capable of being formed into thin plates, not very ductile. Melting point 606°; at a white heat it boils and evaporates; on cooling, crystallizes in octahedrons. *Process.* — It is reduced from the sulphuret of lead (PbS) or galena, a mineral which occurs in cubes with a metallic lustre, by roasting it to convert the sulphur into sulphuric acid, the ore becoming PbO SO_3, and then fusing the sulphate with coal and lime; the metal is extricated, while carbonic acid escapes and sulphuret of lime is left: if it contains silver, the lead is oxidized, and the silver remains. Lead forms

important alloys with numerous metals. *Type metal* consists of 130 parts of lead and 8 antimony. *Fine solder* consists of 2 parts tin and 1 lead; melting point 360°. *Coarse solder*, 1 tin, 4 lead; melting point, 500°.

Dinoxide, Pb_2O 27·, a black powder, obtained by heating oxalate of lead in a retort, or by exposing lead to the air, when it loses its lustre from the production of this oxide. *Protoxide*, PbO 14·, a yellow powder or glass, called also *massicot* and *litharge*. When in scales obtained by placing melted lead on a cupel, and passing a current of air over it, or by calcining the nitrate or carbonate of lead (white lead); when melted, and slowly cooled, it forms octahedrons with a rhombic base. Specific gravity 9·2: volatilises at a white heat; on charcoal, before the blowpipe, the oxygen unites with the carbon, forming CO_2, and the lead appears in melted globules (2PbO and C becoming 2Pb and CO_2). It forms salts with acids, which are generally colourless; the chromate is yellow; the soluble salts are poisonous; the best antidote is sulphuric acid in a diluted state, or alkaline sulphates, which form an insoluble, harmless sulphate of lead. Solutions of this oxide are precipitated in the metallic state by plates of zinc. It forms a glass when fused with silica, sand, or flint, and hence called *flint glass*, of which tumblers and wine glasses are made. Lead vessels, when filled with water, gradually have a line of oxide or carbonate formed at the surface, which becomes diffused through the water, but may be removed by careful filtration. *Sesquioxide*, Pb_2O_3 29·, reddish yellow powder, obtained by adding caustic soda to acetate of lead, till the precipitate which at first appears redissolves, and mixing the liquid with a cold solution of bleaching powder, or hypochlorite of soda, as long as a precipitate falls. It does not unite with acids. *Deutoxide, peroxide, brown* or *puce Oxide*, PbO_2 15·, a brown or flea coloured powder, obtained by adding nitric acid of specific gravity 1·26 to 20 parts of *minium* or red lead ($PbO\ Pb_2O_3$); 18½ parts dissolve, while 1½ parts remain as a *brown* oxide; or by passing chlorine into water, through which red lead is diffused, and then precipitating by caustic soda. It is used as an oxidizing agent in organic chemistry; when rubbed with sulphur it sets it on fire; when heated with chlorohydric acid, chlorine is given out (PbO_2 2HCl becoming PbO, HCl, HO, Cl).

Red Oxide, Red Lead, Minium, $PbO\ Pb_2O_3$ or $2PbO\ PbO_2$ 43·, is formed when oxide of lead or litharge is heated in a reverberatory furnace for forty-eight hours, and constantly stirred. It is a tasteless, insoluble, scarlet powder; specific gravity 9·09. When digested in acetic acid, protoxide dissolves, and the brown powder remains; when heated it gives out oxygen, and is converted into the yellow oxide. It is used as a paint, and is the form of oxide employed in the manufacture of flint glass.

Chloride, PbCl 17·5, occurs in nature as horn lead; artificially it is in white brilliant needles, melting to a white translucent mass. Soluble in 150 times its weight of water. Oxide of lead unites with it in several proportions. *Turner's yellow* consists of PbCl 7 PbO.

Iodide, PbI 28·75, yellow powder, or scales, formed by adding iodide of potassium to a solution of a salt of lead, dissolving in boiling water, or in hot dilute acetic acid; on cooling it falls.

Sulphuret, PbS 15·, *Galena*, occurs in nature abundantly in the formations older than the coal series, as cubes, with a metallic lustre. Specific gravity 7·58. Is easily formed by precipitating a solution of a salt of lead by sulphuretted hydrogen, and is then obtained as a black powder; is converted by nitric acid into sulphate of lead, and by hydrochloric acid into chloride of lead and sulphuretted hydrogen.

Carbonate, PbO CO_2 16·75, *White Lead, Cerussa, Magistery of Lead*, occurs in nature of different shades from white to black in right rhombic prisms. Specific gravity 7·285. It may be formed, artificially, by precipitating acetate of lead by an alkaline carbonate; for commercial purposes, it is prepared by placing sheets of lead over earthen pots filled with weak acetic acid; the apartment being strewed with tan or horse-dung. The temperature of the latter often rises to 150°, the lead becomes corroded by the acid, and then unites with the CO_2 evolved from the dung. It is used as a pigment in the form of a white powder, and constitutes the bases of most paints.

Sulphate, Pb O SO_3 19·, occurs native in white, rhombic prisms, and artificially is prepared by adding sulphuric acid, or an alkaline sulphate to a salt of lead. *Nitrate of Lead*, PbO NO_5 20·75, colourless octahedrons, insoluble in nitric acid, formed by dissolving oxide or carbonate in nitric acid. *Acetate*, Pb O Ac 3 HO 28·75, *Sugar of Lead, Sugar of Saturn*, right oblique angled prisms, sweet, astringent, prepared by dissolving litharge in acetic acid. On the large scale it is formed by melting the lead in a copper vessel into thin sheets. These are placed in earthen pots and half covered with acetic acid; the lead is gradually dissolved. It is employed as an eye water: it counteracts inflammation in the form of a weak solution (1 to 10 grs. to an ounce of water). *Trisacetate*, 3 Pb O Ac 48·375, Goulard's lotion, obtained by boiling equal weights of litharge and acetate of lead in four times their weight of water in a close vessel. It is used as a lotion. *Chromate, Chrome yellow*, Pb O Cr O_3, 20·5, *yellow* powder, obtained by precipitating 100 parts of bichromate of potash with 176 of acetate of lead, and washing it. It is used for painting coach pannels, and in calico printing. *Dichromate*, 2 Pb O Cr O_3 34·5, *Chrome orange*, constitutes the orange spots on blue handkerchiefs; is formed by adding caustic soda to chrome yellow, and may be restored to the yellow state by the

addition of acid. When chrome yellow is printed on cloth, if the cloth be passed through lime water, the colour becomes orange. $2(Pb\,O\,Cr\,O_3)$ and $Ca\,O$ becoming $2\,Pb\,O$, $Cr\,O_3$ and $Ca\,O\,Cr\,O_3$.

Separation. — Lead may be separated from its solutions by SO_3 and evaporation to dryness, or by oxalate of NH_3 in a neutral solution.

TIN. Sn (Stannum) 7·25 *Jupiter.*

Was known in the earliest ages. It is mentioned in Isaiah, 760 years before Christ, where it is said, as it ought to be translated, "I will purify your scoria, and take away your tin, or divided matter;" the root of the term signifying to divide or division. It occurs in nature in two forms, — *Tinstone, deutoxide* or peroxide of tin, and as bell-metal ore, a sulphuret of tin and copper.

Characters. — Tin is a white metal, brilliant; *taste* disagreeable, evolving an *odour* by friction; hardness between gold and lead. Specific gravity 7·285: very malleable, tin leaf or foil, being $\frac{1}{1000}$th of an inch in thickness. Its ductility is small, its tenacity is inconsiderable; a bar of tin $\frac{1}{4}$ of an inch in diameter being broken by a weight of 296 lbs. (*Rennie*). When heated to 392° it can be pulverized; at 442° it melts, and in cooling crystallizes in rhomboidal prisms; can only be volatilised at a strong white heat. When tin is pure it shows no appearance of crystallization on the surface; if we just melt it and pour it into another vessel, it should have a bright surface. *Pewter* is an alloy of 1 part of lead or bismuth, and 20 tin. Nitrate of copper, when moistened and rolled up in tin foil, takes fire and oxidizes the tin.

Preparation. — 1. Tinstone ($Sn\,O_2$), for the purpose of reduction, is first *ground* into a powder. 2. It is washed, so as to separate the impurities, and allow the heavy powder of tin to subside. 3. It is *roasted* in a reverberatory furnace, to remove sulphur and arsenic, with which it is contaminated. 4. It is mixed with limestone and coal, and heated for eight hours in a reverberatory furnace. The coal removes the oxygen in the form of CO_2, while the lime unites with silica and other impurities into a slag. 5. The tin is still further purified by being replaced in the furnace. When just melted, it is allowed to flow into a kettle, the impurities being left behind. It is kept melted in the kettle, and by agitation a scum of impurity collects on the surface, which is removed. The metal is then run into moulds which form blocks, often weighing 3 cwt. Hence the term *Block Tin.* What is termed *stream tin* is obtained by melting it by means of charcoal and bellows. The tin gradually becomes brittle, and is allowed to fall from a height; it splits into irregular prisms, a mark of purity.

Protoxide, Black Oxide (Sn O 8·25).—Black powder, tasteless, insoluble in water; specific gravity 6·66. It is obtained by heating the oxalate of tin, or by dissolving tin in HCl, and precipitating the solution by carbonate of soda, washing the precipitate well, and igniting it in close vessels, or in CO_2. When heated in the open air, it catches fire, burns, and becomes deutoxide (Sn O_2). It is insoluble in NH_3; soluble in Na O; precipitated *brown* by SH; precipitated *brown*, and redissolved by NH_3 SH. It dissolves in SO_3, HCl, and dilute NO_5; by strong NO_5 it becomes deutoxide (Sn O_2). It precipitates gold and mercury, producing with the former the *purple of Cassius* (Sn O_2 Au_2 O + Sn O_2 Sn O 4 HO), a colour used in enamel painting.

Deutoxide, Peroxide (Sn O_2 9·25).—*Tinstone, Yellow Oxide, Stannic Acid,* occurs in nature in yellow or black octahedrons, or more commonly as a 4-sided square prism; hardness 6·5; specific gravity 6·55 to 6·945. Artificially it is prepared by acting on tin with NO_5, or by heating tin to whiteness in the open air, when the metal takes fire and is converted into the yellow oxide. When prepared by these methods, it dissolves with difficulty in acids. When prepared by precipitation with an alkaline carbonate, or alkalies from the deutochloride, it dissolves easily in acids. Deutoxide of tin is precipitated by NH_3, and redissolved by a great excess; also, by NaO, and NH_3 SH.

Protochloride of Tin (Sn Cl 3HO=15·125). — *Salt of Tin,* formed by dissolving tin in HCl, with an excess of the metal until the acid is saturated. The solution is evaporated when the protochloride separates in long needles, or 4-sided prisms. The anhydrous chloride is formed by distilling equal parts of tin and calomel; a gray body passes over, which becomes solid on cooling. The crystals are employed to remove oxygen, and also as a mordant in dyeing, and in calico-printing.

Deutochloride (Sn Cl_2 16·25).—*Fuming liquor of Libavius, Permuriate of Tin,* is obtained by distilling 6 parts of tin rubbed with 1 mercury, and 33 corrosive sublimate (Sulze). It is also formed by burning tin in chlorine gas. It is colourless, like water; specific gravity 2·25; smokes in the air; 3 parts of this liquid, mixed with 1 of water, form *butter of tin;* a thick fluid which dissolves in more water. It acts on oil of turpentine. It does not precipitate gold.

Sulphuret of Tin (Sn S 9·25). — Gray brittle substance, formed by fusing tin with sulphur. Sp. grav. 5·267.

Deutosulphuret (Sn S_2 11·25). — *Mosaic Gold.* Gold-coloured substance obtained by subliming a mixture of tin, 6 parts; mercury, 3; sal ammoniac, 3; flowers of sulphur, 3½. Muriate of ammonia, cinnabar, and protochloride are volatilized, while mosaic gold remains. *Sulphate* (SnO SO_3). Needles by dissolving Sn in SO_3.

Bismuth. Bi. 27. (Ancients.)

Characters.—Bismuth is found native, in the form of a reddish-white metal, consisting of brilliant plates adhering to each other.

Process.—It is separated from the rock in which it occurs, by fusion, which takes place at 476° (*Irvine*); 496 (*Crichton*). When cooled slowly, it crystallises in parallelopipeds, crossing each other at right angles. Its primary form is an octahedron; specific gravity 9·822 (Hatchett); 9.833 (Herapath). By exposure to the air it loses its brilliancy, in consequence of its union with oxygen; obtained pure by heating the subnitrate with charcoal.

Oxide of Bismuth ($Bi\ O_3$) 30·.—Straw-yellow powder, without taste and smell, insoluble in water, soluble in NO_5. Melts by heat into an opaque glass. Soluble in caustic soda. The oxide may be obtained by burning the metal in the air, when a blue flame is produced and the oxide sublimes (flowers of Bismuth), or by igniting the nitrate of bismuth. At a red heat the colour of the oxide is brown: but, on cooling, pale yellow.

Trisnitrate of Bismuth ($3\ Bi\ O_3NO_5$).—*Flake-white, Magistery of Bismuth.* This is the only form of bismuth of interest. The process for preparing it forms a beautiful experiment. It consists in dissolving a portion of the metal in nitric acid in a flask, and then pouring the nitric acid solution into a pint or more of water, in a tall jar. A fine white precipitate immediately falls, which is *flake white;* $3Bi\ O_3\ 3NO_5$ being converted into $3Bi\ O_3\ NO_5$, and 2 atoms NO_5 being set free. It is much used in medicine in many dyspeptic cases where the mucous membrane of the bowels seems to be affected, and particularly in the diarrhœa of children.

Peroxide of Bismuth ($Bi\ O_5$), *Bismuthic acid, Quintoxide,* is formed by fusing hydrate of soda with oxide of bismuth, and is purified by boiling with caustic soda solution. A brown powder is obtained, which is washed with NO_5, and then with water. It resembles deutoxide of lead.

Fusible metal, which dissolves in hot water, is formed by heating in a crucible 3 parts of tin, 8 bismuth, and 5 lead. The addition of a little mercury increases the fusibility. It is used to form casts for electrotype.

Mercury. Hg. (Hydrargyrum) 12·5. (Ancients.)

Quicksilver, Argentvive. Characters.—White silvery fluid, without taste and smell. Specific gravity 13·568; when solid at —38·66°, it is 14·465, and is then malleable. Boiling point 660° or 680°.—It volatilises at this temperature, and can therefore be purified easily from fixed impurities. Specific gravity of vapour 6·976. When solid, crystallizes in octahedrons.

Preparation.—Mercury occurs in nature united with sulphur in the form of cinnabar (Hg S), a red mineral in acute rhomboids and regular 6-sided prisms. The sulphur is removed by distilling the cinnabar with lime or iron filings in iron retorts; the mercury is allowed to condense in vessels filled with water, sulphuret of calcium and SO_2 being formed. In Spain it is reduced in a peculiar furnace without any addition, by bringing the flame in contact with the hot ore; the sulphur is converted into ($S O_2$) sulphurous acid.

Amalgams are compounds of mercury with other metals. *Alloys* are compounds of all other metals except mercury. *Mirror* or *Tin Amalgam*, used in silvering the backs of looking-glasses, consists of 3 parts mercury and 1 tin. *Fluid Amalgam* is formed of 3 mercury, 1 lead, and 1 bismuth. These metals are sometimes used to adulterate mercury; but when so mixed, its drops are not spherical, but *drag a tail*. *Amalgam* for electric machines, consists of 1 zinc, 1 mercury, 4 tin.

Suboxide (Hg_2 O), *Dinoxide, Black oxide, Ethiops per se, Mercury of Moscati*. Mercury tarnishes by exposure to air. When calomel is precipitated by soda or potash, the black oxide falls (Hg_2 Cl and Na O becoming Hg_2 O and Na Cl). Lime water has the same action, and thus forms what is called in medicine *black wash*, which is used for sores. Specific gravity 10·69: forms salts with acids, which are generally colourless; precipitated *black* by NaO.

Oxide (Hg O 13·5), *Red Precipitate, Red Oxide, Deutoxide, Binoxide, Peroxide.*—In regular red octahedrons, red powder, or in red scales; formed by heating mercury to 600° in the open air or by heating the nitrate; taste acid and disagreeable: when pure, it gives off no coloured fumes. Specific gravity 11; becomes black by heating, setting zinc and tin on fire; used in surgery as a caustic to clean sores. Its salts are colourless or yellow, and poisonous; NH_3 digested on HgO forms a *yellow powder* or a hydrate of an amide and oxide of mercury (Hg N H_2, 2 Hg O 3H O). Lime-water throws down the yellow oxide and forms the surgical *yellow wash* (Hg Cl, Ca O forming Hg O, and Ca Cl). The yellow precipitate is HgOHO or hydrate, and becomes red by heat.

Subchloride (Hg_2 Cl 29·5), *Dichloride, Protochloride.*—*Calomel, Sweet Mercury*. Mercury absorbs chlorine and forms calomel, which may be sublimed in white 4-sided prisms, or as a white powder. Specific gravity 7·175. The usual process for making it consists of three stages:—1. Sulphate of mercury is formed by boiling 12½ mercury with 15 sulphuric acid (Hg and $2SO_3$ becoming HgO SO_3 and SO_2 evolved); 2. Each atom, or 18½ grains, of sulphate are then triturated in a mortar with 12½ of mercury, and 7½ of common salt (Na Cl). 3. This mixture being placed in

a flask and heated, the calomel sublimes ($Hg\,O\,SO_3$, Hg and Na Cl becoming $Hg_2\,Cl$ and $NaO\,SO_3$). This experiment may easily be made by heating a small flask, which is to be supplied with a perforated cork and a short tube passing through it, set in a small sand-bath over a gas or spirit lamp. Calomel is soluble in 12,000 parts of water, tasteless, not poisonous; but is speedily in part converted in the stomach into corrosive sublimate, which is a poison. When ammonia is added to calomel, *a gray precipitate* is formed, consisting of $Hg_2\,Cl$, $Hg_2\,NH_2$. It is formed at the expense of 2 atoms of calomel and 2 of ammonia ($2Hg_2\,Cl$ and $2NH_3$ becoming $Hg_2\,Cl$, $Hg_2\,NH_2$ and $NH_3\,HCl$); gray precipitate and muriate of ammonia being formed. By heating with chlorides, calomel is converted into corrosive sublimate; hence its action in the system.

Chloride (Hg Cl. 17). — *Corrosive Sublimate, Bichloride, Perchloride.* Fine white semitransparent mass of prisms, cubes, or rhomboids, or white powder, soluble in 18 parts of cold and 2 of hot water. Specific gravity 5·139. *Taste* acrid and caustic; virulent poison, uniting with and destroying live organic substances, but preserving them when dead. Hence it is used to keep anatomical preparations and for embalming dead bodies. The usual process for preparing it consists of three stages: 1. A sulphate of mercury is prepared by heating cautiously in a basin or flask equal parts of sulphuric acid with mercury until the mercury disappears; the addition of a little nitric acid facilitates the operation ($2SO_3$ and Hg becoming $Hg\,OSO_3$, and SO_2 evolved); 2. 18½ parts of the sulphate are triturated in a mortar with 7½ parts of common salt (Na Cl); 3. The mixture is introduced into a flask with a perforated cork and tube, as with calomel, and sublimed; the action being as follows: sulphate of mercury, common salt ($Hg\,O\,SO_3$, and Na Cl), form corrosive sublimate, Glauber salt ($Hg\,Cl$ and $NaO\,SO_3$). Corrosive sublimate may be crystallised in large prisms by solution in water and slow evaporation; it dissolves in alcohol and ether, and sublimes entirely; it dissolves in H Cl; and on the addition of protochloride of tin, a black precipitate of finely divided mercury falls, which becomes running mercury by heat. Iodide of potassium gives a scarlet precipitate. A plate of copper becomes brown in its solution. When swallowed, it produces a pain in the stomach and bowels — diarrhœa and vomiting. The *antidotes* are white of egg, milk, and iron filings, the two former combining with it, as may be proved by adding a solution of corrosive sublimate to a solution of white of egg.

White precipitate ($Hg\,Cl$, $Hg\,NH_2$) is formed by adding NH_3 to a solution of corrosive sublimate: $2Hg\,Cl$ and $2NH_3$ become $Hg\,Cl\,Hg\,NH_2$ and $NH_3\,HCl$. When boiled with water it becomes a yellow powder ($2Hg\,Cl + Hg\,NH_2$), and 2HO become

$HgCl$, $Hg NH_2$, HgO and $NH_3 HCl$. When boiled with NaO white precipitate gives out NH_3, and does not become black as calomel does.

Black sulphuret, Disulphuret ($Hg_2 S$). — Black powder obtained by precipitating the subnitrate with sulphohydric acid (SH).

Sulphuret or *Red Sulphuret* (HgS). — *Cinnabar, Vermilion*, occurs in nature, but may be prepared artificially by fusing 1 part of sulphur with 6 mercury, and subliming the blackish red mixture in a covered crucible, occasionally removing the lid and stirring it.

Subiodide (Hg_2 I 40·75), *Diniodide*.—Yellowish green powder, formed by dropping an iodide into a solution of the subnitrate of mercury, or by rubbing in a mortar 25 parts of mercury with 15¾ parts iodine, with some alcohol.

Iodide (HgI 28·25). — Scarlet crystalline powder, formed by adding iodide of potassium to corrosive sublimate, or by rubbing in a mortar 12½ parts Hg with 15·75 I, with the aid of alcohol, so as to form a red powder, which is to be boiled with a strong solution of common salt until it dissolves. On cooling it deposits in fine carmine scales. Slightly soluble in water, very soluble in iodide of potassium. Specific gravity of its vapour 15·68. Becomes a yellow fluid at 400°. Both of these iodides are used in medicine, internally and in the form of ointment.

Cyanide of Mercury (Hg Cy 15·75).—Square prisms prepared by dissolving 2 parts yellow prussiate of potash in 15 boiling water, adding 3 parts dry sulphate of mercury, boiling for 15 minutes, filtering while hot, and crystallising out the cyanide. Additional crystals may be obtained from the mother liquor. It is used for preparing Cyanogen (p. 81), and is poisonous.

Sulphate of Mercury ($HgO\ SO_3$) is formed in the process for calomel. When boiled with water, it becomes yellow, being converted into *Turbith mineral* ($3HgO\ SO_3$). *Subnitrate of mercury*, ($Hg_2O\ NO_5\ 2HO$). — Colourless prisms formed by dissolving mercury in cold dilute nitric acid. *Nitrate of mercury* ($2HgO\ NO_5\ 2HO$) is obtained by dissolving mercury in hot nitric acid.

Estimation of Tin, Bismuth, and Mercury. — *Tin* is best estimated by treating it either in the metallic or compound state, with an excess of NO_5 evaporating to dryness, treating with water and filtering. The deutoxide remains: every 9¼ grains of which contain 7¼ of tin. *Bismuth* is usually precipitated by carbonate of NH_3, having previously removed all HCl by evaporation, and substituted NO_5. *Mercury* is separated by dissolving in HCl, and adding protochloride of tin in a small flask and boiling, and after the appearance of globules, pouring into a porcelain crucible, washing, drying at a low heat, and weighing.

BASIC RADICALS.

Class VI. Noble Metals.

Gold.	Rhodium.
Platinum.	Iridium.
Palladium.	Osmium.
Ruthenium.	

These metals require an intense heat to melt them. They are best dissolved by a mixture of NO_5 and H Cl: their oxides are reduced to the metallic state by heat, and they form but a limited number of combinations, their oxides especially showing no tendency to unite with acids.

Gold. Au. (Aurum) 12·25. (Ancients.)

A *reddish yellow* metal; crystallising in cubes, softer than silver; the most malleable and ductile body known: one grain can be drawn out in wire to 500 feet, and can be beat into gold leaf of 56¾ square inches. Specific gravity 19·3. Melts at 2015° F.: expands when fused, having a greenish colour, and contracts when cooling; in powder it is brown.

Gold occurs in nature in a free state, in the beds of rivers, mixed with sand, from which it is separated by washing. Sometimes it is mixed with silver, which can be dissolved out by means of sulphuric acid, the gold remaining unacted on. English gold coin contains 1 twelfth of copper. A sovereign weighs 123·274 grains, and contains 10·273 grains of alloy.

Gold amalgam is a compound of gold and mercury, employed for gilding metals. The metals are immersed in the amalgam until a combination is formed. The mercury is then dissipated by heating the metal; the dull gold is then brightened by polishing with a brush, termed *burnishing*. *Jeweller's gold* is an alloy of gold and copper with silver. *Green gold* used in jewellery is an alloy of 3 silver and 7 gold. When gold contains much copper, it is liable to tarnish, which may be removed by immersion in ammonia. Gold is deposited on other metals by electrotype; the gold is dissolved in aqua regia, the solution is evaporated in the water-bath to remove the excess of acid; the residue is dissolved in 130 times its weight of water, and 7 times its weight of bicarbonate of potash is added. In this mixture the metal to be gilt is immersed. Instead of the alkali, cyanide of potassium is now

employed, and the poles of a battery are introduced into the fluid. Gold is soluble in a mixture of nitric and hydrochloric acids, but not in any single acid.

Dinoxide, suboxide (Au_2 O 25·5). — Green powder obtained by precipitating the subchloride (Au_2 Cl.) by caustic soda.

Sesquioxide (Au_2 O_3 27·5). — Brownish powder easily decomposed by light; does not combine with acids, but forms feeble compounds with bases. It is formed by adding a slight excess of caustic magnesia to a solution of gold in nitro-hydrochloric acid; the oxide precipitates in union with magnesia; wash the precipitate; digest in nitric acid, which removes the magnesia, and leaves the oxide in the state of a hydrate, but it parts with the water at 212°. When heated with hydrochloric acid, sesquichloride is formed; an oxide is formed by passing a spark of electricity through gold leaf placed between two plates of glass; the gold burns, and leaves the trace of the spark; it burns also when exposed to the action of the battery: the *oxide* forms fulminating gold when digested with ammonia. Gold has less affinity for oxygen than any other metal. Hence its value in retaining its colour without tarnishing.

Purple of Cassius. — A fine purple powder, a compound of gold and peroxide of tin, formed by adding to a solution of chloride of gold a solution of protochloride of tin. It is used as a pigment for glass and porcelain, and may be prepared by dissolving 1 part of grain tin in 9 of NO_5 diluted with 2 of water; 3 parts of common salt are added, as the addition of salts promotes the separation; and then 80 parts of water are added. The chloride of gold is then added in drops.

Sesquichloride (Au_2 Cl_3 38).—Pale yellow needles formed by igniting gold leaf in chlorine gas, or by dissolving gold in *aqua regia* (a mixture of 1 NO_5 and 3 H Cl), evaporating away the excess of acid, and dissolving in water; the crystals are deliquescent, and form a yellow solution. Gold is precipitated in the metallic state from this solution by phosphorus, sulphate of iron, iron, zinc, copper, &c. oxalic acid, and the vegetable acids, and salts of the alkalies. Pure gold is often obtained by adding protosulphate of iron to this salt, and washing with dilute H Cl and water. This salt is used in the electrotype for gilding, as a caustic in surgery, as an application to cancerous surfaces, and also as an internal remedy in syphilis. *Fulminating gold* (Au_2 Cl_3 2 NH_3 HO), yellow brown powder, formed by precipitating sesquichloride by NH_3. *Subchloride* (Au_2 Cl. 29).—Yellow mass, insoluble in water, obtained by heating the *sesquichloride* up to the melting point of tin. Converted by water into gold and sesquichloride.

Sesquisulphuret (Au_2 S_3. 30·5).— Formed by precipitating the sesquichloride by SH. It is a yellow powder, much employed

in painting on pottery. It is made for commercial purposes, by fusing in a crucible 3 parts of potash, 9 sulphur, and 1 gold; pouring out the melted mass and digesting in water with access of air. Acetic acid is then poured on to divide it finely.

PLATINUM. Pt. 12·25. (Wood 1741.)

White metal, like silver, but less bright, harder than copper, very ductile and malleable. Specific gravity 21·5. Cannot be melted in a crucible, but only by the oxyhydrogen blowpipe and by the galvanic battery. It can be welded at a red heat.

Preparation. — It occurs in nature, along with various other metals, in South America and Russia. To separate them the ore is digested in dilute aqua regia; a black powder of iridium and osmium remains undissolved. The solution is mixed with sal ammoniac dissolved in 5 times its weight of water; the yellow precipitate washed with sal ammoniac water, and gently heated in a black lead pot to drive off the sal ammoniac; the black powder called *spongy* platinum is then rubbed in a wooden mortar, and finally placed in a mould and beat into an ingot.

Protoxide (PtO 13·25). — Black powder, obtained by digesting caustic potash or soda with protochloride of platinum. Acids dissolve it, and form greenish-brown solutions. *Deutoxide, Peroxide* ($Pt O_2$ 14·25). —Yellowish-brown powder, formed by precipitating the chloride by SH; dissolving the sulphuret in NO_5; and heating to drive off the excess of acid. Precipitate the SO_3 by nitrate of barytes; filter; pour in NH_3 or KO, till half of the oxide falls. This oxide possesses faint acid properties. *Sesquioxide* ($Pt_2 O_3$ 27·5).—Gray powder, formed by precipitating the sulphate by NH_3; boiling the precipitate in weak potash, so as to remove the SO_3, and obtain a fulminating compound; on treating it with NO_5, the sesquioxide remains.

Protochloride (Pt Cl 16·75). — Greenish-gray powder, or olive-brown, obtained by heating the deutochloride to 450°, insoluble in water, SO_3 NO_5 and PO_5. By ignition, the metal remains. From this compound the black protoxide is obtained by caustic alkalies.

Deutochloride, Perchloride ($Pt Cl_2$ 21·25). — A reddish-brown powder, obtained by evaporating the solution of platinum in nitro-hydrochloric acid till the excess of acid is removed. When dissolved in water or alcohol, it forms a compound of sal ammoniac, insoluble in 1 part of ether and 2 of alcohol ($Pt Cl_2$, NH_3 HCl), and a similar compound with chloride of potassium ($Pt Cl_2$ KCl), by which we are enabled to separate potash and ammonia from their solutions. Every 28 grains of platino-sal ammoniac contains 2·125 of ammonia, and every 30·75 grains of platino-chloride of potassium are equivalent to 6 of potash.

If Pt Cl be heated in contact with NH_3 a greenish salt is

formed, Pt Cl NH_3 (Magnus), which contains the elements of NH_3, but not that gas itself. When heated longer with NH_3 it dissolves, and on evaporation affords yellowish crystals, (PtCl, N_2H_6, HO or at 212° (Pt N_2H_6) Cl (Reiset), but contains no ammoniacal gas. If this salt be heated to 280° NH_3 is given out, and a yellowish salt remains, PtCl NH_3 or (Pt NH_3) + Cl, but differing from Magnus's salt in colour, and in being soluble in hot water (Peyrone). If Magnus's salt be dissolved in NO_3, Pt is deposited and NO_4 given out, the solution depositing white scales (PtCl N_2H_6) O + NO_5 (Gros).

Platinum, from its having little tendency to oxidise, and from its high melting point, is of great value in the laboratory for crucibles, and in the sulphuric acid manufacture for stills. *Spongy Platinum* is obtained by heating the platino-sal ammoniac salt. It possesses the property of igniting when a stream of hydrogen is projected on it, and of converting pyroxylic spirit into acetic acid, by causing the latter to combine with oxygen. *Platinum Black.*— A black powder, obtained by placing a rod of zinc in the chloride solution, adding a few drops of sulphuric acid; the platinum precipitates; impurities may be removed by digesting in hydrochloric acid. For *Platinocyanides*, see p. 85.

PALLADIUM. Pd. 6·75. *Wollaston*, 1803. White metal. Specific gravity when fused 11·3. Harder than hammered iron; brittle. It is obtained from the crude ore of platinum, by solution in nitro-hydrochloric acid, and precipitation by cyanide of mercury. The yellowish white precipitate (Pd Cy) when ignited leaves metallic palladium, which may be hammered into an ingot like platinum. It has a greater affinity for oxygen than platinum, for when strongly heated it becomes blue on the surface; it dissolves in cold nitric acid without disengagement of gas. It is slightly acted on by SO_3 and HCl. *Protoxide* (Pd O 7·75). — Black powder precipitated from the salts of this oxide by caustic potash or soda, or by igniting the nitrate; loses its oxygen when heated. *Deutoxide* (PdO_2 8·75). — Yellowish brown, by adding caustic potash to the solid potash chloride of palladium. *Protochloride* (Pd Cl 11·25). — Black powder, formed by evaporating the solution of palladium in aqua regia. *Deutochloride* ($PdCl_2$ 15·75) exists only in solution, and is formed by dissolving the protochloride in hydrochloric acid. *Iodide* (PdI 22·5). — Black powder obtained by adding a solution of palladium to a soluble iodide. From its insolubility in water it affords an excellent method of estimating the amount of iodine in solution.

RHODIUM. R. 6·5. *Wollaston*, 1804; *ῥόδον, a rose. Characters.*—White metal. Specific gravity 10·64. Insoluble in all acids; very hard. *Process.* — It is obtained from the raw ore of platinum, in which it exists to the extent of 1 to 3 per cent. after the separation of the platinum and palladium by immersing in it a plate of zinc. Rhodium mixed with some platinum, copper, and lead falls. The two first are dissolved by nitro-hydrochloric acid, and the rhodium is crystallised by the addition of common salt, a double salt being formed; the compound salt of platinum is soluble, and that of rhodium insoluble in alcohol; the salt is thus separated, dissolved in water, and the metal precipitated by a plate of zinc. *Protoxide* (RO 7·5). — Black powder, supposed to be obtained when the potash sulphate of rhodium is precipitated by carbonate of soda. *Sesquioxide* (R_2O_3 16·). — Yellow powder, obtained by igniting powder of rhodium with nitrate of potash and caustic potash, washing with water and HCl; insoluble in acids. *Sesquichloride* (R_2Cl_3 26·5).—A dark brown powder; decomposed by heat into R and Cl. Obtained by precipitating the double potash chloride of rhodium with fluo-silicic acid. *Sulphuret* RS ? 8·5. — A blueish-gray powder, obtained by heating the metal and sulphur.

IRIDIUM. *Tennant*, 1803 (from Iris, *colour*). Ir 12·25. *Characters.* — White metal; the least fusible of all metals. Specific gravity 24; resists the action of

all acids; very hard. *Process.*—It exists in the black matter which remains on treating the ore of platinum, in which it exists to the extent of from 1 to 5 per cent. with nitro-hydrochloric acid. This matter is a compound of osmium and iridium. They are separated by fusing the black substance with potash in a silver crucible; dissolving the potash out with water, when the osmium is taken up of an orange colour. The residue is to be alternately treated with potash and HCl till it dissolves. On the evaporation of the red chloride of iridium, the salt crystallizes in octahedrons. When a plate of iron or zinc is placed in the solution of this salt, the metal falls. *Protoxide* (IrO 13·25.) —Greenish-gray when moist, black when dry; obtained by precipitating IrCl by potash. *Sesquioxide* (Ir_2O_3 27·5).—Dark brown as hydrate, blueish black when dry, formed by igniting the potash chloride of iridium with an alkaline carbonate. *Deutoxide* (IrO_2 14·25?).—Imperfectly examined, but probably an acid. *Teroxide* IrO_3? brownish-yellow hydrate, formed by precipitating the double potash salt with an alkaline carbonate. The *blue* oxide is supposed to be composed of IrO and Ir_2O_3. *Protochloride* IrCl 16·75.— Formed by passing Cl over ignited iridium: forms double salts with the alkaline chlorides. *Sesquichloride* Ir_2Cl_3 38·, obtained as a black mass by igniting iridium with nitre and digesting in HCl. *Deutochloride* $IrCl_2$ 21·25, formed by dissolving the last chloride in nitric and hydrochloric acids; by evaporation it is reconverted into the sesquioxide. *Terchloride* $IrCl_3$ 25·75? has only been obtained in union with chloride of potassium in black octahedrons. Iodine unites with iridium, forming a binodide (IrI_2) a black powder; it forms four combinations with sulphur.

Osmium. *Tennant*, 1804 (from *ὀσμη, smell*) Os. 12·5. *Characters.*— A white metal like iridium; specific gravity 10·; soluble in nitric acid and aqua regia; when finely divided it takes fire when heated in the open air; at common temperatures does not oxidise in the air. *Process.*— It is obtained by distilling the fused mass of the osmium iridium compound and nitre. Osmic acid passes over, which is heated with chloride of mercury; metallic osmium remains. *Protoxide* OsO 13·5. — Greenish black powder, obtained by precipitating the double salt of potash chloride of osmium with caustic potash. *Sesquioxide* Os_2O_3 28·? Deep blue, only obtained in union with the protoxide. *Deutoxide* OsO_2 14·5 *Osmous acid.*— Black powder, obtained by precipitating the potash chloride with an alkaline carbonate. It possesses acid properties, forming a crystaline salt with potash. *Quateroxide, Osmic Acid* (OsO_4 16·5). — White brilliant crystals, slowly soluble in water, very soluble in alcohol and ether; acrid vapour, unites with alkalies, but does not tinge litmus; distinguished by its giving a deep blue with a solution of gallic acid; obtained by burning osmium in contact with oxygen, and by distillation as above. Osmic acid does not displace CO_2 from its combinations, and is scarcely, therefore, an acid any more than sugar. *Tests.*— Disagreeable odour; brown with AgO NO_5 and BaCl; black by SH. *Protochloride* OsCl 17·—dark green sublimate, obtained by heating the metal in chlorine. *Deutochloride* $OsCl_2$ 21·5. — Red sublimate, formed when the stream of Cl, in the last experiment is continued; soluble in a small quantity of water, but decomposed by a larger amount. Two other chlorides, the sesquichloride (Os_2Cl_3), and Terchloride ($OsCl_3$), are supposed to exist; but they have hitherto only been found in combination. The *potassium bichloride* of osmium is formed by mixing metallic osmium with KCl, and passing chlorine over the mixture at a red heat; it is a red powder dissolving in water, and affording octahedrons by evaporation.

Ruthenium. *Claus* 1844. Ru 6·5.—A deep gray metal, pulverulent, with difficulty fusible; oxidises when heated in the air; the oxide is not reduced at a white heat; hydrogen, however, reduces it at a red heat; fused with nitre it gives a deep green mass. It is obtained by fusing the insoluble residue from platinum ore with equal parts of nitre, by repeated fusions and action of water and aqua regia. Ruthenium is obtained in the form of a beautiful orange yellow solution. By adding NO_5, potash oxide of ruthenium falls, containing silica. This precipitate is dissolved in HCl and evaporated almost to dryness; the silica remains; the solution is filtered, and to the liquor is added KCl; potash chloride of ruthenium crystallizes out, from which the metal and its compounds are obtained. Hydrogen reduces the metal from its double chloride. Ruthenium combines with 4 doses of oxygen and 3 of chlorine. It is distinguished from iridium and rhodium by its salts having a reddish brown colour, by its affinity for oxygen, by the solubility of its double potash salt in alcohol, and by SH not precipitating the metal entirely, but leaving a blue solution, due probably to a solution of a portion of protoxide.

CHAPTER VI.

Organic Chemistry.

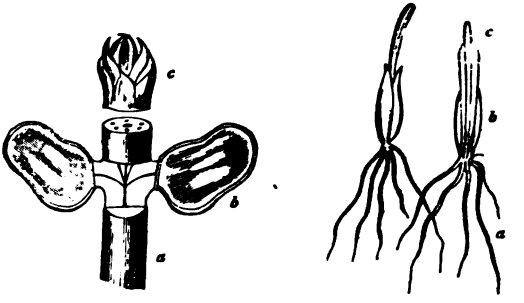
MAIN CONSTITUENTS OF PLANTS AND THEIR PRODUCTS.

Organic chemistry treats of the composition and properties of those bodies which are produced in the organs of living beings, while inorganic substances may be formed without any connection with organised beings. These beings, again, being divisible into two great classes, viz. into those which are capable of sensation, or animals, and those which are destitute of this power, or plants, there is a subdivision usually admitted in the science of *vegetable* and *animal* chemistry. It is true that, as we descend in the animal world, a point is attained where no nerves (the organs of sensation) can be detected; but such beings, it is highly probable, hold an intermediate station in the animal and vegetable world. Animals and vegetables have, in their incipient condition, precisely the same appearance. When examined by a miscroscope, a slice of a plant is found to consist of a series of cells, or compartments, united together so as to form a kind of honeycomb; and so it is with animals. But chemistry, at the earliest period of organic life, detects a difference between vegetable and animal cells: for if we boil the matter of which they are composed in caustic soda, the animal cell yields ammonia; proving the presence of *nitrogen* in addition to *carbon*, *hydrogen*, and *oxygen*, while the vegetable cell contains no nitrogen, but is wholly constituted of the three last bodies. We must consider then a bean as composed of a cluster of cells (fig. 89.); and that when placed in water, or in a moist soil, a series of new cells are united to the old ones, in two directions; the radicle, or root, passing downwards, and the stem, or plumule, rising upwards. The root and stem are, therefore, long clusters of new cells added to the extremities of the roots. As they increase in number the root lengthens and the stem ascends to the air, where the bark expands into leaves, corresponding in number to the divisions or cotyledons of the seed. Between the cotyledons and the plumule there appears to be no

Cotyledons of a bean (*Grew*).

direct communication (fig. 90.). Hence it is inferred that the inorganic food is carried from the earth by the roots to the

90 *Germination (Grew).* 91



Bean. Oats.

a. Root. *b.* Cotyledon. *c.* Plumule.

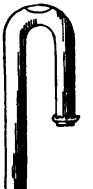
cotyledons, there undergoes some change, and from thence is transmitted to the radicle, to be elevated by the plumule. Besides inorganic salts, such as the alkaline phosphates, chlorides of sodium and potassium, phosphate of lime and magnesia, which must be all in a state of solution before they are taken up by the roots, it is inferred that ammonia and water are also extracted from the soil by plants and carried up in the sap by the spiral vessels of the alburnum or sap-wood. The leaves by their under surface absorb carbonic acid from the atmosphere, separate the oxygen, and retain the *carbon* of this gas. The leaves also receive the sap, which is carried by spiral vessels, between the pith and bark, to the highest point of the plant, fig. 94. The leaves separate water from the sap, and throw it out on their surface. Hence they are said to act the part of the stomach and lungs of the animal system. After the sap has been purified by the leaves, it descends by the bark, of which the leaves are merely an expansion, to the lower parts of the plant; and, during its course, in many species excretes on the surface substances known under the names of gums and resins. It is from this purified descending juice, or sap, that plants derive the matter which causes them to increase in bulk. The cause of the ascent of the sap through narrow tubes, from the root to the summit of a lofty tree, has been long a question of interest among physical botanists. Some have ascribed it to what is known under the title of capillary attraction, which is well illustrated, when we take a very narrow glass tube, not much wider than that of a thermometer, and leaving both extremities open, place one end

of it in a tumbler of water. We shall speedily find that the water will rise in the tube higher than the surface of the water in the tumbler. Another explanation has been given of this curious phenomenon. If we take a long glass tube, 4 feet long, and $\frac{1}{2}$ inch bore, and tie over its lower extremity with a piece of bladder; fill it half full of a saturated solution of common salt, coloured by infusion of litmus, and then introduce it into a jar of pure water, so that the water in the tube and jar shall stand at the same level. In the course of 24 hours the fluid in the tube will be found to be much higher than that of the exterior vessel. The result of this experiment is similar to that of placing two gases of different densities on opposite sides of a porous membrane; the lighter gas passes through most rapidly, while the heavier gas is slower in its progress. The complicated stem of a plant is conceived to afford a series of similar experiments. When an ingoing current increases the volume, it is said to rise by *endosmose*, or accumulation from without; when it decreases by an outgoing current, it is said to descend by *exosmose*, or accumulation from within. The ascent of the sap very much depends on the presence of leaves; so that if we cut off a branch from a tree, and dip the lower extremity in a solution of acetate of iron, leaving the upper leaves, the wood will be impregnated with the colour, but not so distinctly if they are removed.

Ascent of Vegetable Sap and Animal Fluids.—Some light has been thrown on the ascent of the sap and animal fluids, not only by the phenomena of endosmose, but also by the experiments of Hales and Liebig. Fig. 92. represents a barometer tube filled with water, the wide end being covered with ox-bladder, and the small end open and inverted in mercury. In the course of a few hours we observe that the mercury ascends, and continues gradually to rise, in consequence of the evaporation through the bladder. Hence there is a constant tendency to the formation of a vacuum, which is prevented from actually being produced by the ascent of the mercury. If we view the bladder as representing the leaves of trees, or as the animal skin, we have a close parallel, and may form some notion of the enormous force occasioned by the evaporation on these surfaces. If the bladder be covered with oil, the evaporation ceases; or if it be allowed to become dry, neither air nor water will pass through it. The contact of water is essential to this action. If the ascent of the sap, then, be dependent upon some such principle, we can easily understand how any obstruction to the ascent would be attended by such a disease as the potato blight, which is observed always to commence in the stem. In fig. 93. the two extremities of the tube are tied with bladder, the siphon being filled with water. Evaporation goes on at both ends, and a vacuum occurs at the upper bend, into which, however, air makes its way. If we immerse the lower part of the long limb in a blue solution of salt, the coloured fluid soon becomes visible above the bladder, and it gradually rises, displacing the water which evaporates through the bladder of the short limb; the same observation applies to other fluids, so that as a general expression it appears that all liquids

92

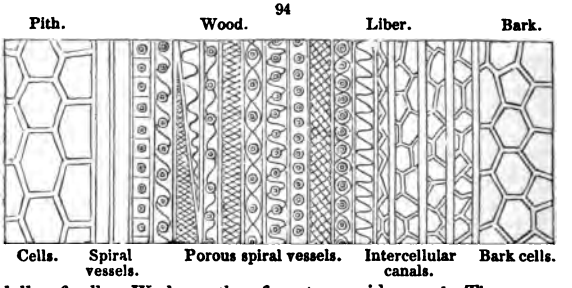
93



move towards the membrane from which evaporation takes place, the amount of motion being proportional to the rapidity of evaporation and to the temperature and state of moisture of the atmosphere. As the vacuum tends to form in the inside of the bladder, we observe that the atmospheric pressure renders the exterior surface of that membrane hollow or concave. Hence any fluid placed on it externally will be pressed inwards, and be absorbed as the expression is in medicine; and during this action evaporation must be impeded.

The structure of a plant supplies us with an useful arrangement in the study of vegetable chemistry. Plants consist essen-

Section of Taxus baccata (*Kieser*.)



tially of cells. We have, therefore, to consider:— 1. The nature of the matter of which they are composed. 2. The substances secreted in the cells, as starch, woody matter. 3. The composition of the solid matters existing in the sap, as sugar, gum, &c. 4. Other secretions of plants comprising the alkaloids and colouring matters. 5. The excretions or resins. Such a classification cannot be strictly maintained in the present state of the science; but it affords a connection between physiology and chemistry.

Manures. —As plants extract a certain amount of salts from the soil, which are entirely removed at harvest, it is obvious that the soil will become gradually impoverished, unless steps are taken to replace the matter which is carried away. This process is termed manuring, and hence a true theory of manures is to restore to the soil what is removed by the crops grown upon it. In the present state of our knowledge it is inferred, that the analyses of the ashes of plants supply us with the proper ingredients to constitute manures.

I. SUBSTANCES FORMING THE CELLS.

Cellulin, Cellulose (Lignin of *Prout*), $C_{12} H_{10} O_{10}$.

Properties. — A white, solid diaphanous body insoluble in cold water, alcohol, ether, and oils. Specific gravity 1·525. Strong sulphuric acid and phosphoric acid attack it without heat, and

render it soluble in water, and capable of being precipitated by alcohol. Caustic soda swells it up and acts on its surface. In this way it softens it for bleaching. It is not affected by iodine, except in some mushrooms, where a violet colour is produced.

Preparation.— Obtained in its purest form from cotton or linen. These substances are to be torn into shreds; washed with cold, then with hot water; digested in boiling caustic soda for 2 or 3 hours; diffused through water, and a current of chlorine gas passed; after which it is digested in caustic soda. It is then washed successively with water, acetic acid, boiling water, digested in ether and alcohol, and lastly dried in a vacuum at 212°. By a similar process, but with more difficulty, it may be extracted from wood. The sporules of some mushrooms produce a violet colour with iodine, and hence they appear to contain cellulin. NO_5 in a concentrated state, dissolves cellulin, and converts it into *xyloidine* or *nitramidine* ($C_{12}H_9O_9NO_5$), which is precipitated by the addition of water. This substance may be formed by dipping paper into strong acid, and washing with water. It constitutes an excellent match-paper; cellulin is also the basis of gun cotton, or *ternitramidine*, ($C_{12}H_7O_7 3NO_5$), already described under nitric acid (p. 69.) To obtain *Dextrin* a soluble form of cellulin, we triturate in a mortar 100 parts of fine surgeon's lint with 140 parts $HOSO_3$, added drop by drop, and stir until a gummy mass is formed; dilute with water, and saturate with chalk or barytes. By the addition of alcohol dextrin is precipitated, which possesses the same composition as cellulin, and by the addition of SO_3 and heat, is capable of being changed into sugar. In every respect it resembles a similar product from starch.

Woody Matter. — The interior of the walls of the cells is lined as trees grow, by a hard woody matter, which is deposited after the formation of the cell, as a kind of encrustation. It may be separated from the cellular matter, by cutting the wood lengthways, and then pounding it in a mortar into a pulp with water. This paste is treated successively with soda, hydrochloric acid, alcohol, and ether. Caustic soda then dissolves the lignin, which is again precipitated by an acid. The precipitate consists of 3 bodies, one of which is *brownish yellow* and is soluble in alcohol, ether, and water, containing 68 per cent. of carbon; the second *brown*, soluble in alcohol, insoluble in ether, containing 51 per cent. of carbon; and the third a *gray* body insoluble in alcohol, ether, and water, and containing 48 carbon. The terms *fungin* and *suberin*, have been applied to the woody matter of mushrooms and cork.

Decay of Wood. — Wood is apt to decay if not properly seasoned; that is, the sap which contains albumen must be washed out; otherwise a species of fermentation takes place, the albumen acting like yeast. The cellulin and ligneous

matter disappear in part, in the form of carbonic acid and water while humus or mould remains. Oak wood ($C_{36}H_{22}O_{22}$), for example, is converted by exposure to the air into humus ($C_{34}H_{18}O_{18}$), by the loss of 2 carbonic acid and 4 hydrogen oxidised by the air to form water ($2CO_2$, $4HO$). To prevent the fermenting action of the albumen, wood is seasoned by exposing it to the weather; or it is put into a running stream of water to wash away its sap; or it is steeped in solutions of salts, which unite with the albumen and coagulate it. Upon this principle the corrosive sublimate (Kyan's patent) and chloride of zinc (Burnett's patent) act. Wood coal ($C_{33}H_{21}O_{16}$), and even pit coal, are supposed to be produced by a similar action. Probably the latter has also been subjected to the influence of heat. If we subtract 9 atoms CO_2 3 water and $3CH_2$ from the above formula for wood, we obtain the expression for splint coal, $C_{24}H_{13}O$. The coals are divided into 4 species for practical purposes:—1. Splint and cherry coal, for producing heat, contain about 82 per cent. of carbon; 2. Caking coal, for the same purpose, of similar composition; 3. Anthracite, containing above 90 per cent. of carbon; 4. Cannel, parrot, or gas coal, with from 65 to 75 per cent. of carbon, adapted for lighting purposes. These coals when distilled yield heavy and light oils, containing carbonic acid, leucol, aniline, &c., and naphthaline, a crystalline body, which is of interest in consequence of the facility with which its hydrogen can be replaced by other substitutional bodies.

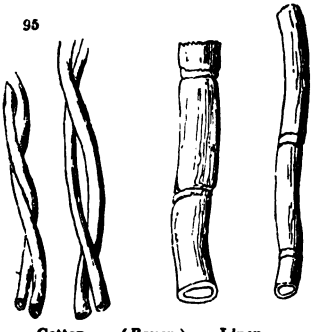
Bleaching or *blanching* is the process for whitening cellulin, or depriving it of a yellow tinge which it naturally possesses. This is effected by — 1. Washing the goods with water; 2. Boiling them in soda to remove grease, and also to soften the surface of the cellulin; 3. Steeping them in a weak solution of bleaching powder, or *chemic*, as it is technically called (hypochlorite of lime); 4. Steeping in weak sulphuric acid, or *souring*, as this is termed.

Paper making.—Paper being made from waste linen and cotton rags, and even from waste cotton wool, straw, and ropes, it is obvious that it consists entirely of cellulin, its quality depending upon the purity of that substance present. The rags are subjected to the same bleaching processes as in the manufacture of cloth. 1. They are sorted and cleaned according to their quality; 2. They are shaken in a revolving cylinder; 3. Boiled in caustic soda; 4. Reduced to pulp by means of a beating engine; 5. The pulp is bleached; 6. It is combed out into fibres, and allowed to flow into a chest, where it is ready for being converted into paper: 7. Paper is made from the pulp either by the hand or the machine; by the hand, it is formed into sheets by a mould of wire; it is then dried, and is in the condition of *blotting* paper; 8. To convert it into *writing* paper it is soaked in a

solution of glue and alum; 9. It is then subjected to the action of hot iron plates and rollers. When thus pressed, three or four times, it is termed *rolled* or *hot pressed*, and when more frequently *glazed* paper. The blue colour of some kinds of paper is given by cobalt mixed with the size.

Dyeing consists in the application of colouring matter, so as to cause it to adhere to cloth. If we take a piece of cotton or calico, and place it in a solution of madder, and then wash it, the colour is entirely removed. To fix the colour, therefore, a chemical application is required, which, being first attached to the cloth, then unites with the colour. This substance is termed a *mordant* or *biter* (from mordeo, *I bite*). It may be easily illustrated by dipping cloth in a solution of acetate of lead, and then in a solution of bichromate of potash. The lead is the *mordant*, and fixes the chromic acid, thus depositing chrome yellow on the cloth. The most satisfactory explanation of the process is that the acetate of lead enters into the tube (fig. 95.) of which the cotton and linen consists, fills it like a bag, and remains there to receive the chromic acid. (*Crum.*) If we dissolve alum, which is a valuable mordant in water; precipitate the alumina by ammonia; throw it on a filter and wash it; mix it by means of a spatula in a solution of madder or Brazil wood, and throw the whole on a filter; the liquid will pass through clear, while the colouring matter and alumina remain combined on the filter, and may be dried. This experiment demonstrates the affinity between the colour and the mordant. — *Calico printing* consists in the application of colours to the cloth, by means of blocks and cylinders (as in book printing), after the use of a mordant. *Wool* differs (fig. 96.) from cotton and linen, in being a minutely jointed tube.

95



Cotton. (*Bauer.*) Linen.

96

Wool.
(*Girardin.*)

ACTION OF HEAT ON WOOD. — When wood is burned in the open air, a quantity of the carbon escapes combustion in the form of *soot*, which is a light mixture of impure carbon, sulphate of ammonia, and other salts. When wood is distilled in close vessels it is converted into charcoal, which remains behind, into acetic acid, pyroxylic spirit, tar and oils, and into a large amount of combustible gases, which are evolved.

Methyle. — C_2H_3. — A gaseous radical, existing in pyroxylic or wood spirit, obtained in the distillation of wood. This gas is formed by dropping cyanide of ethyle upon potassium. Wood spirit is one of the first products of wood distillation. It is decanted from the other products, and rectified over lime. When deprived of all its water by chloride of calcium, it is a *hydrate of the oxide of methyle*, (C_2 H_3 O HO), burning with a pure flame, and giving out so much heat that it answers well for laboratory lamps; dissolves resins and salts like alcohol. Specific gravity of vapour 1·12. *Methyle oxide* (C_2 H_3 O) is obtained by distilling the previous body with sulphuric acid in a retort, and receiving the gas which is formed over mercury; it is colourless, odour ethereal, and burns with a pale flame. *Chloride* (C_2 H_3 Cl), obtained by distilling 2 parts common salt, 1 part spirit, and 3 SO_3, over water; it is a colourless gas, burning with a flame white in the middle and green round the edges. The *bisulphate* is procured by boiling with sulphuric acid. *Barytes sulphate of methyle* (C_2 H_3 O SO_3, Ba O SO_3) is a salt in square plates, obtained by saturating the preceding salt with carbonate of barytes.

Formyle (C_2 H). — A hypothetic radical, supposed to be the basis of *Formic acid* (C_2 HO_3), a substance produced when spongy platinum is brought in contact with the vapour of pyroxylic spirit. This acid was first extracted from red ants by Halse (1671), and distinguished as a peculiar acid in 1812, by Gehlen. It may be prepared by boiling 1 part of starch with 4 of sulphuric acid, and 4 water, allowing the liquor to cool, and then adding gradually 4 black oxide of manganese (Mn O_2), and distilling. Formic acid comes over by the following action: C_2 H_2 O_2, or sugar produced by the SO_3 upon starch, and $2MnO_2$ $2SO_3$, become C_2 HO_3, and $2Mn$ OSO_3, and HO. Formic acid has a peculiar odour; it unites with bases. *Formate of Lead* is produced by saturating the acid with carbonate of lead; it is more insoluble in water than acetate of lead, and may be distinguished by this character. The acid is obtained in its strongest state by distilling the formate of lead with sulphuric acid.

Chloroform (*Terchloride of Formyle* C_2 HCl_3).—An oily ether, with a fine odour. Specific gravity 1·5. May be formed by mixing in a half gallon retort 8 oz. bleaching powder, 24 oz. water, 1½ oz. alcohol (specific gravity ·840), and distilling with a gentle heat. The chloroform passes into the receiver with

some alcohol and water. Wash it first with its own bulk of water to remove Cl; pour off the water; add CaCl to the oil, and allow it to stand for an hour. Pour off the oil, and distil with its own bulk of SO_3. It is used as a stupefacient. (*Simpson*).

Artificial Oil of Ants (*Furfurol*), is obtained by distilling diluted sulphuric acid with bran or meal (*Dobereiner* and *Emmett*). Its composition is $C_{15}H_6O_6$ (*Stenhouse, Fownes*).

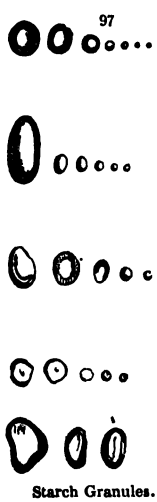
In the tar and oils which are distilled from wood spirit we find *Paraffin*, a substance crystallizing in scales from the heavy oil. *Creasote* is obtained by distilling wood tar with SO_3, and afterwards with soda or potash. It is a colourless oil, with a peculiar odour; dissolves resins, coagulates albumen. When diffused through water it answers for preserving animal substances, acts as a caustic when applied to decayed teeth, and removes toothache. It is the preservative principle in smoked hams, obtained from the wood soot. In wood tar there also exist *Eupion*, *Picamar*, *Capnomore*, *Pittacal*, *Cedriret*, *Pyren*, and *Chrysene*. The oils from coal, which is considered to be a condition of decayed wood, yield *Naphthaline* ($C_{20}H_8$), a body crystallizing in scales; *Aniline* or *Cyanol* ($C_{12}H_7N$); *Carbolic Acid* or *Phenyle* ($C_{12}H_5OHO$); *Leucoline* ($C_{18}H_8N$); *Picolin* ($C_{12}H_7N$); and other substances of little interest. Allied to these are the bitumens of the Dead Sea and Trinidad; the naphtha of Persia and Birmah, supposed to be the turpentines of extinct pines.

II. STARCHY SUBSTANCES IN THE CELLS OF PLANTS.

Starch, Amylum, Fecula, Amiline, Amidine $C_{12}H_{10}O_{10}$. — In the cells of plants we find deposits of granular matter, which is characterised by its giving a blue colour with iodine. It is collected sometimes in large quantity in the bulbs, as of potatoes, and more especially in the seeds, as of wheat, oats, barley. Starch has been considered by some as occupying the position of fat in animals, as being stored up to serve as food to the plants, and as capable of conversion into gum and sugar. Starch granules consist of successive layers of the matter of which they consist, and vary in size and form in different plants, and even at different stages of the growth of the same plant (fig. 97.) By means of this character we are able to detect under the microscope various adulterations, as of arrowroot by potato starch.

Starch is prepared by steeping wheat in open casks or vats, in cold water, till it becomes soft and ferments; the lactic or acetic acid produced dissolving the albuminous matter. The wheat is then placed in sacks, and subjected to pressure in a vat filled with water. The starch is squeezed through the sacks and falls to the bottom of the water. It is then washed with repeated

additions of water, and dried.



Starch Granules.
(*Dumas.*)

The purest starch is obtained however from potatoes. There are various forms of starch familiarly known. *Arrowroot* is obtained by washing the roots of the *Maranta arundinacea*. *Tapioca* from the roots of the *Iatropha manihot*. The juice washed from it contains a poison (HCy). *Cassava* is an impurer form of this starch. *Sago* is extracted from the root of the sago palm in India (*Sagus raphia*). All of these forms of starch contain about 3½ per cent. of albumen, while wheat starch contains 2½ per cent. *Salep* is a gum or modification of starch (*Bassorin*) from the root of the orchis.

Characters. — Starch is without smell and taste. Specific gravity 1·53; insoluble in cold water, alcohol, and ether. When hot water at 212° is poured on starch it is converted into a thick paste of a translucent appearance, produced by the swelling out rather than solution of the granules. If this paste is mixed with a large portion of water and filtered, a clear solution passes through which yields a blue colour with iodine in its cold state, disappearing when heated, and returning when cold. A portion remains undissolved on the filter, but by continued boiling the greater portion dissolves. Acetate of lead precipitates starch. *Dextrin*, a soluble form of starch having the same composition, may be prepared by causing acids to act on starch. It may be prepared readily by heating 100 parts of starch paste with 5 parts of extract of malt, at a temperature of 140° to 150°. As soon as it is no longer coloured blue by iodine, the dextrin is produced. It may be separated from sugar by yeast. When evaporated it possesses the characters of gum-arabic. It is soluble in weak alcohol. *British gum, Soluble starch, Leiocome.* — This is used by calico-printers. It can be made by roasting starch, or by mixing 400 parts of potato starch with 20 water and 1 nitric acid (specific gravity 1·42), and heating to the temperature of 220°. It is used for making surgical bandages. *Inulin* is obtained from the dahlia, inula, and other roots. It differs from starch in giving with iodine a *brown* colour, and consists of C_{24} H_{21} O_{21}. *Lichenin*, procured from Iceland moss

and other lichens, is a gummy matter, having the same constitution as starch, and is not affected by iodine. *Diastase*, a substance allied to the preceding, procured from malt. The malt is macerated in cold water, pressed, filtered, and alcohol added; the diastase precipitates; it is solid, white, amorphous, soluble in water, insoluble in alcohol; it possesses the remarkable property, when present in minute quantity, of bursting the starch granules; 1 part of it is sufficient to render soluble 2000 of starch.

Flour, Meal, Grain. — Substances known under these names are deposited in the seeds of certain plants, as wheat, oats, barley, maize or Indian corn, beans, peas, &c. When heated they give out water; and when the temperature is raised they blacken, and yield vinegar, and the odour of burned animal matter, proceeding from the formation of ammonia at the expense of the nitrogen existing in part of their constituents; as they constitute the food of the greater portion of mankind, it is obvious that they must contain the same substances which exist in animals. The following table exhibits the analogy between wheat flour, blood, and milk: —

Flour.	*Blood.*	*Milk.*
Fibrin	Fibrin	
Albumen	Albumen	Albumen
Casein	Casein	Casein
Glutin	Colouring matter	
Oil and starch	Fats and oils	Butter
Sugar and Starch	Sugar, fat	Milk sugar
Chloride of potassium		
Chloride of sodium		
Phosphate of soda	Ditto	Ditto
— lime		
— magnesia		
— iron		

Analysis of Flour. — The mode of analysing flour so as to demonstrate the presence and quantities of these constituents, is as follows: — Take half a pound of best flour, place it in a towel, and fold the cloth up so as to form a bag; pour water or allow it to flow from a pipe upon the flour, squeezing the flour and allowing the milky fluid to pass into a vessel placed below. Continue to wash with water until the fluid passes through perfectly clear. The water removes every soluble substance from the flour, and leaves upon the cloth a glutinous adhesive substance, which, however, is a mixture of various bodies. To examine it, it must be dried at 212°, and then boiled in alcohol repeatedly. The alcoholic fluid, when poured off, on cooling deposits flocks of casein or curd. When evaporated further, it yields an adhesive matter, glutin, which has the same composition as casein, and upon evaporating the alcohol entirely an

oily matter and sugar remain. The greater portion of the adhesive matter is, however, insoluble in alcohol; it is *Fibrin*, identical in composition with the muscular matter of animals, but retaining the earthy phosphates, which are insoluble in water and weak alcohol. The watery solution squeezed through the cloth, deposits, on standing, starch, and retains in solution the chlorides and phosphate of soda, and albumen. The albumen is obtained by heating the solution, when it coagulates; it has the same composition as the white of egg.

Analysis of Potatoes. — The potatoes, deprived of their skins, are to be rasped down into a pulp. The pulp is then placed on a towel and washed with water, as with flour, the starch passing through, and casein or curd being dissolved in the water. The starch is allowed to subside, and the liquor poured off and boiled down. A portion of acetic acid is added, when the casein separates in flocks. These are thrown on a linen or cotton filter, and washed with water. The matter remaining on the first towel is woody matter, and is to be triturated in a mortar with hot water, and washed till it gives no precipitate with iodine. The products are dried at 212°.

In order that these flours may act as proper nutritive substances, it is necessary that the proportion of their constituents should bear some certain relations to the component parts of the animal of which they are to form a part. Thus, in order to form healthy blood, the food ought to contain all the salts enumerated, and the amount of albumen should bear a proper proportion to the starch, from which it is believed the fat of animals is derived. In good wheat the relation of the albuminous matter to the starch and sugar is about 1 to 8; while in milk it is from 1 to 2 in cows, and 1 to 6 in human milk. Hence it is found advantageous that mothers should use animal food to a certain extent in addition to bread. (See *Experimental Researches on the Food of Animals*, p. 167.)

Fibrinous Substances in Flour. — These are the substances which sustain the waste of the muscular part of animals, and they are all characterised by containing nitrogen and sulphur. These substances pass unchanged into the animal system, and are deposited in the solid form. They may therefore be prepared from animals. *Fibrine* (C = 52·18 H 7·09 N 16 O 23·48 S 1·25). — White powder when prepared from fish, with a yellow tinge from other sources; NO_5 turns it yellow, nitrogen being evolved; SO_3 turns it to a yellow jelly which does not dissolve. *Acetic acid* converts it to a jelly dissolving in hot water and precipitated by yellow prussiate of potash. HCl dilute gradually dissolves it; KO dissolves it gradually, and acetate of lead added to the solution and boiled, gives a black precipitate of PbS (Scheele, 1780). *Fibrin from Silk* is insoluble in acetic acid, soluble in SO_3, giving a red colour; precipitated by infusion of

nut-galls; soluble in HCl, in NO_8 in KO. Vegetable fibrin is prepared from flour, by the process already described. From blood it is prepared by beating this fluid when fresh with a stick to prevent coagulation, and then filtering through a towel, and washing till a white gelatinous substance remains. *Albumen* has nearly the same composition as fibrin, but it contains 2 per cent. of sulphur. It is a white powder, with a shade of yellow when prepared by evaporating a solution of the white of egg at a temperature of 160°, washing the coagulum, drying it at 212°, pulverising, washing with water, boiling with alcohol and ether, to remove fat; when dried below 120°, albumen is soluble in water. It is soluble in HCl, KO, the solution blackening acetate of lead and silver (Scheele, 1780); acetic acid and yellow prussiate of potash precipitate albumen from its solutions in water. The salts of tin, lead, bismuth, silver, and mercury, precipitate albumen. The most delicate test is corrosive sublimate, and hence it acts as an antidote to this poison.

Oxidation. — When 1 part of albumen, 3 bichromate of potash, and $4\frac{1}{2}$ SO_3, and 30 water, are mixed, in a few hours the albumen dissolves, and the liquid when distilled contains hydrocyanic acid, metacetonic aldehyd, butyric aldehyd, oil of bitter almonds, butyric acid, acetic acid, aldehyd. The same products are yielded by fibrin. *Casein.* — Brownish powder, resembling gum when pure, having nearly the same composition as fibrin, with 1 p.c. of sulphur, which can be detected by the same tests (*Scheele*, 1780); casein is not coagulated by heat as albumen is, but it is precipitated by acetic acid which does not redissolve it, which happens with the mineral acids. It is obtained from milk by precipitation with acetic acid, filtering, washing, dissolving in a solution of carbonate of soda, precipitating by acetic acid, washing, repeating the process with soda until it is pure. Casein exists in potatoes, peas, beans, and may be extracted by digestion in water and coagulation by acetic acid. Casein is apt to attract oxygen, and to change in the air. The casein of milk may be coagulated by *Rennet*, an albuminous matter dissolved from the stomach of animals by water. A similar action is produced in some forms of serum which contain fibrin in solution. No deposit takes place until a piece of fibrin be introduced, when the whole coagulates into a jelly. (*Dr. A. Buchanan.*) *Solid potash* when fused in a silver basin with casein gives a mass affording to water and acetic acid *Tyrosine* (C_{16} NH_9 O_5), fine needles. The mother liquor after their deposition contains *Leucine* (C_{12} NH_{12} O_4), a crystalline body in scales, obtained also from gelatine, volatilising at 338°. From the action of potash are also obtained by distillation valerianic acid, butyric acid, the former at the expense of the leucine.

Oxidation. — Casein when treated as albumen above described, yields, by distillation, aldehyd, acetic acid, formic acid, valerianic

acid, metacetonic aldehyd, butyric aldehyd, and oil of bitter almonds. Casein from beans I find yields similar products.

III. SUBSTANCES IN THE JUICES OF PLANTS.

Gums are exudations from plants, and differ from starch in not being coloured by iodine, and in being converted into mucic acid (C_{12} H_8 O_{14}), a white crystalline powder, by nitric acid; and from sugar, by not fermenting with yeast, although they have the same composition with starch and sugar.

Cerasin, cherry-tree gum. — An exudation from the cherry and plum trees, and is characterised by its insolubility in *cold* water; it is tasteless, pulverisable, insoluble in alcohol; does not ferment when mixed with yeast; when boiled in water it is converted into arabin or gum-arabic. It is extracted from raw cherry-tree gum by digesting it in cold water till every thing soluble, consisting principally of arabin, is taken up; it possesses the same composition as starch: this gum is of no value.

Bassorin, gum-tragacanth, salep. — The principal constituent of gum-bassora, tragacanth, and of salep the root of the orchis; in cold water it swells up and forms a mucilage without dissolving; hot water does not dissolve it completely; alkalies dissolve it; it is used with sugar as a remedy in colds. *Arabin, gum-arabic, gum-Senegal.* — Found in Africa as an exudation from species of acacia; soluble in cold and hot water, and therefore of great value to the calico printer; although its place is partly supplied by the cheaper soluble starch from potatoes. Specific gravity 1·3; loses, in a vacuum, 16 p. c. of water; precipitated from its solutions by alcohol, the precipitate being soluble in potash; precipitated by acetate of lead, nitrate of mercury. *Mucilage, vegetable mucus*, obtained from linseed, common symphytum, malva, Irish moss, or sea-weed, by digesting in cold or hot water, and precipitating by alcohol and drying; it is less translucent than common gum. *Pectin* (C_{12} H_7 O_{10}). — When the juice of apples, gooseberries, &c. is pressed out, boiled, filtered, and then mixed with alcohol and set aside, a colourless jelly separates in a few days, which may be further purified by solution in water, and precipitation by alcohol; when dried it is translucent and resembles isinglass; boiled with NO_5 it is converted into oxalic and mucic acids. *Pectic acid* (C_{12} H_7 O_{11}). When transparent and fluid pectin remains in contact with vegetable albumen, it coagulates into a jelly, and is insoluble in water but soluble in alkalies; and becomes an acid with the same composition as pectin, uniting with lime, lead, &c. Pectic acid may be procured by expressing the juice of carrots until it comes away colourless, adding to 50 parts of the residue 300 of water and 1 of caustic potash, boiling for a quarter of an hour, filtering and pressing the

residue; the filtered liquor coagulates; the acid is then precipitated by HCl; it is translucent, scarcely soluble in cold water, but soluble in hot.

Metapectic acid is obtained by boiling pectic acid for some hours with potash; it is deliquescent, while pectic acid is almost insoluble; has an acid taste, and forms very soluble salts. It has the same composition as the preceding bodies. The change of one of these bodies into the other takes place rapidly in growing fruits, and is promoted by the presence of acids. A thin section of a green gooseberry exhibits in its fleshy part an infinite number of cells, with thick walls; these become thinner from day to day, until they break and allow the fluid to pass into the adjoining cells. This fluid is acid, and reacts upon the exterior matter, producing pectin. Green gooseberries when washed contain little soluble matter; but if they are acted on by tartaric acid, malic, or SO_3 acids, soluble pectin is formed.

Sugars are obtained from the sap of various plants. Of these there are several kinds. *Common sugar, cane sugar* (C_{12} H_9 O_9 2 HO). Cane sugar is obtained by expressing the sugar cane between rollers; it is then mixed with a pint of lime to 100 gallons, placed in a copper vessel, and heated to 140°; drawn off, and boiled in a copper boiler. The concentrated juice is placed in empty hogsheads, and drained through a hole in the bottom. *Muscovado* sugar is left, and the molasses drain off. It is purified by solution in water, filtering through bags, draining through animal charcoal, and evaporation in a vacuum. When concentrated to a crystalline state, it is placed in inverted conical earthenware or painted iron vessels (*a*), from which the molasses drains, by a hole in the bottom, into an earthen receiver (*b*) placed below; this is *crushed* or *shaved* sugar: when converted into loaf sugar it is further washed with syrup and purified by animal charcoal. *Characters*, colourless; crystallizes in irregular 4 and 6 sided rhombic prisms, specific gravity 1·606; giving out light when pounded in the dark; melting into a colourless fluid at 356°. *Sugar candy* is crystallized by immersing strings in syrup. *Crushed* or *shaved sugar* is prepared for sale by breaking up the sugar with a shaving machine. Sugar unites with lime and barytes; these compounds consist of C_{12} H_9 O_9 Ca O HO, and are decomposed by CO_2. The lead compound contains 2 atoms of oxide. A compound with common salt ($2C_{12}$ H_9 O_9 Na Cl 3 HO) exists in cubic crystals. At 420° sugar loses 2 atoms of water and becomes a black substance termed *caramel*; at a higher temperature it gives out CO_2, CH_2, oil, acetic acid, charcoal; distilled with lime it affords two fluids, *Acetone* (C_3 H_3 O). *Metacetone* (C_6 H_5 O_2 C O_2 and HO). Sulphuric acid converts sugar into a substance resembling mould or humus. NO_5 forms

98

oxalic acid, and saccharic acid, $C_{12} H_6 O_{11}$ 5 HO with CO_2. Sugar dissolves oxide of copper; hence it is a good antidote for salts of this metal. *Grape sugar, starch and honey and fig sugar, wood sugar, diabetic sugar, glucose* ($C_{12} H_{14} O_{14}$ or $C_{12} H_{11} O_{11}$ 3 H O), may be obtained by boiling for 36 hours 99 parts of starch with 1 of sulphuric acid and 400 of water, replacing the water evaporated, and concentrating. *Characters.* — From an alcoholic solution crystallizes in imperfect square plates; but from an aqueous solution in crystalline grains; specific gravity 1·38; it dissolves in SO_3, while cane sugar is blackened by that acid; alkalies do not colour cane, but blacken grape sugar. *Sugar of milk, lactin.* $C_{24} H_{24} O_{24}$. — Obtained by evaporating whey, in 4-sided prisms, terminated by 4-sided pyramids; differs from the other sugars in the circumstance that by N O_5 it is partly converted into *mucic acid* and partly into oxalic acid. Specific gravity 1·54; it ferments with yeast. *Glycyrrhizin, liquorice sugar.* — A black mass which does not ferment with yeast, and which may be purified to a yellow mass by alcohol. *Mannit* or *manna* ($C_6 H_7 O_6$.—Obtained from the fraxinus ornus and certain sea weeds (fucus saccharina), by means of alcohol, in long white needles or prisms which do not ferment. It is one of the products of the *mucous fermentation* when saccharine juices of plants are exposed to a temperature of 95° — the sugar being converted into *mannite* ($C_6 H_7 O_6$) and lactic acid ($C_6 H_5 O_5 = C_{12} H_{12} O_{11}$). *Lactic acid* is easily prepared by dissolving 1800 parts of sugar in 9500 of water, — adding some curd of cheese and milk of lime, and exposing it to a temperature of 90°. In the course of 4 or 5 weeks lactate of lime is formed, and from the salt the lactic acid may be separated by dilute SO_3; it is a thick fluid, with an acid taste, soluble in water and alcohol; dissolves phosphate of lime, which acetic acid cannot do. It exists in sour milk, in the muscles of animals, and probably in the blood. Lactic acid may be obtained from sour whey by evaporating to the consistence of syrup, digesting in alcohol, and saturating this solution with milk of lime. On distilling off the alcohol, *lactate of lime* in needles remains. When heated to 266° lactic acid loses its water, leaving a bitter yellow residue, *anhydrous lactic acid.* At 482° it begins to decompose into carbonic acid and carbonic oxide. Among the products of its distillation at a low temperature are *Lactide*, or lactic acid deprived of 2 atoms water, and *Lactone* $C_{10} H_4 O_4$ — *Lactamide* $C_6 H_4 O_4 NH_3$ is obtained in prisms by heating lactide in contact with ammonia. By boiling with water the hydrous acid is reproduced. Bases unite with it by displacing water. *Test for lactic acid.* — Lactate of copper when treated with caustic potash yields a deep blue colour. With lime a portion of the oxide of copper precipitates, and the remainder is in solution. Acetate of copper is entirely precipitated by lime.

Changes in Sugar. Vinous Fermentation, and derivatives.

Fermentation. — Sugar is subject to a peculiar species of decomposition termed fermentation (from *fermento*, I puff up), apparently depending on the tendency which all bodies having a complicated composition have to assume a simpler form. If we take a solution of sugar in a flask, and add to it a small portion of *yeast*, or *ferment*, or *leaven*, which is albuminous matter in a state of decomposition, and expose it to a temperature of 70°, small bubbles of gas will soon be observed rising to the surface of the solution, and if these are made to pass into lime water by means of a bent tube, (fig. 63.) carbonate of lime will be formed, while the liquid in the flask acquires the odour of spirits. In this instance the sugar simply divides into 2 portions, and takes up nothing from the yeast; $C_{12} H_{12} O_{12}$, or sugar, becoming 2 alcohol = $C_8 H_{12} O_4$, and $4CO_2 = C_4 O_8$. Putrid cheese and flesh act in the same way; the particles of these substances being in a state of motion, are supposed to communicate the same tendency to the particles of the sugar. Hence the term fermentation has been applied, perhaps improperly, to various other actions, which are supposed to be induced by analogous causes. Thus, urine, when exposed to the air, speedily gives out the smell of ammonia, in consequence of the conversion of urea into that substance, by uniting with 2 atoms of water. This change is said to be produced by the urinous fermentation, or, as some would have it, an action by contact (*catalytic*).

Alcohol, Hydrous Oxide of Ethyle ($C_4 H_5 OHO$). — The well-known product of the fermentation of sugar. In its most familiar forms of beer, and various kinds of spirits, it is obtained by fermenting the solution of the soluble parts of barley or oats, and distilling the alcohol, thus produced: —1. The barley is first converted into malt, or, in other words, the starch of the grain is changed into sugar. 2. The sugar is dissolved out of the grain by infusion in water; the resulting infusion is called *wort*. 3. The wort is mixed with *yeast*, and the sugar converted into alcohol and carbonic acid (*Wash*). To form the malt, the grain is steeped in water for 3 or 4 days; it is then spread out on a floor till germination commences, and frequently turned. On the 14th day, when the root and plumule are pretty long, the germination is suddenly checked by placing the grain in a kiln at 90°, and afterwards at 140°. The effect of germination is to burst the starch granules, and to convert it into soluble sugar, passing through the stage of dextrin. The malt is afterwards ground between rollers, and placed in the *mash tun*, where it is exposed to the action of water at 165°. The remaining starch is still further converted into sugar, and the infusion becomes finally a

dark-coloured solution or *wort*. It is cooled to 70°, placed in the *fermenting tun*, and mixed with yeast. The fermented wort, or *wash*, constitutes the source both of beer and spirits. If the alcohol is allowed to remain in the wash, the fluid is termed a fermented liquor.

Small Beer is a dilute or weak wort fermented, and contains 1¼ per cent. of alcohol of specific gravity ·825. *Ale* is a stronger wort, containing 7 per cent. of alcohol. *Porter* contains 4¼ per cent. It is made with malt dried at a high temperature, and slightly charred, from which it derives its colour. *Brown stout* contains 6¾ per cent. *Burton ale* 8½ per cent.

Wines are prepared by fermenting the expressed juice of the grape. Like beers and ales they vary in strength and in flavour, according to the concentration and source of the juice. *Champaigne* is one of the weakest wines; it contains 12 to 13 per cent. of alcohol. *Hock*, 13 per cent. *Claret*, 13 to 16. *Sherry*, 19 per cent. *Port*, 23¼ per cent. Hence 5 glasses of sherry contain nearly 1 of alcohol; and 4 of port somewhat less than 1 of alcohol.

Spirits. — When the worts are heated in a *still*, supplied with a refrigerator and receiver, the alcohol passes over and leaves the *spent wash* in the still. *Whisky* is prepared from barley and oats. *Highland whisky* seems to derive its peculiar flavour from the malt being made and dried with *peats*, which give out *creasote*, and other volatile oils, by the combustion of the vegetable matter of which they are composed. *Brandy* is prepared from wine, and flavoured with burnt sugar. The name is derived from the German *brand wein*, burnt wine. *Rum* is distilled from the sugar cane. *Gin*, *Hollands*, and *Scheidam* are distilled from barley, and flavoured with juniper, turpentine, and other substances. The two latter names are derived from the localities of their preparation. *Samshoo*, a Chinese spirit obtained from fermented rice. *Arrack*, a similar impure spirit made in Bengal. *British brandy* is whisky said to be flavoured with nitric ether, and various mixtures.

Characters. — Common spirits, and whisky, have a specific gravity of ·910 to ·915, containing 50 per cent. of alcohol. When they have been distilled their density becomes ·890 to ·880. A second distillation produces *rectified spirit*, of the spec. grav. ·843 to ·835, with 82 to 85 per cent. of alcohol. To remove the whole of the water, it is necessary to distil with chloride of calcium, or quicklime, salt of tartar (carbonate of potash), or to expose rectified spirit in a vacuum along with quicklime. The spirit is placed in one basin, and the lime in another; the air is pumped out until the spirit begins to boil, and is left for some days at the usual temperature. The lime takes the water and leaves the spirit (absolute alcohol of ·794). If a bladder be filled with spirit,

tied up, and hung in a warm apartment for some days, water escapes through the bladder and leaves a strong alcohol. Proof spirit of the excise has a spec. grav. of ·91838, and is said to be above or below *proof* when it is stronger or weaker than this. The term *proof* is derived from the old mode of testing spirit: the spirit was poured over gunpowder and ignited; if the powder exploded towards the end of the combustion, the spirit was said to be above proof; if it did not explode, it was below proof. At present, when we say that spirit is 10 over proof, we mean that 100 gallons to be reduced to proof strength, would require the addition of 10 gallons water, while 10 under proof shows that 10 gallons of water require to be subtracted to bring it up to proof. The strength of spirits is determined by taking the specific gravity either by means of the bottle (see page 7.), or more rapidly by the hydrometer. Alcohol is a transparent, colourless, volatile fluid, with a peculiar pleasant smell, acting first as an intoxicating agent when taken internally, and in larger quantities as a poison. Absolute alcohol boils at 171°, of ·914 at 181½°, of ·831 at 175°. It has never yet been rendered solid by the greatest cold and pressure; it does not conduct electricity; when mixed with water, heat is given out and the bulk of the fluid contracts; it rapidly extracts water from the air, and takes water from animal and vegetable substances when they are immersed in it; hence its use in preserving these bodies from decay, as in anatomical museums. Alcohol is much employed on this account; and, from its being a convenient solvent, in pharmacy, to form *tinctures*; thus we have *tincture of iodine, tincture of sesquichloride of iron, tincture of rhubarb, aloes*, &c. It dissolves various salts, as nitrates of lime, cobalt, copper, alumina, magnesia, chlorides of Zn, Al, Mg. Fe, Cu; it crystallizes with certain salts, as CaCl, MgO NO_5, CaO NO_5, Mn Cl, Zn Cl, and forms *alcoates*. — (*Graham.*)

Experiments. — 1. Dissolve a small portion of camphor in alcohol, and then pour water into it; the camphor is removed from the alcohol, and swims on the surface. 2. Dissolve some chloride of strontium in alcohol, and set fire to the solution in a porcelain basin; the flame has a fine crimson colour, proving the solution of the salt. 3. Take a jar or tumbler; pour into it half a tea spoonful of alcohol; place a plate of glass over the mouth of the tumbler, and agitate until the fluid is invisible; then ignite the vapour of the alcohol, and place the open end of the tumbler in water. The water rises into the glass, showing the formation of a vacuum by the combustion. It is upon this principle that cupping glasses extract blood from the body.

Bread making, Panification. — The usual method of making bread is to mix yeast with dough or moist flour, and allow it to ferment; the sugar is converted into alcohol and carbonic acid. The gas is generated throughout the dough; but cannot escape,

from the adhesiveness of the mass. But when placed in the oven at 450°, the gas expands, and finally escapes, leaving the whole of the bread a mass of little bladders or vesicles. A good baked loaf, or a well-raised loaf, is therefore bread in which the carbonic acid has been equally generated throughout the mass; but by the usual method the CO_2 is formed at the expense of the sugar of the flour, occasioning the loss of at least 6½ per cent. Any method of diffusing carbonic acid through dough, will form superior bread to that prepared by fermentation. *Soda scones* are made by mixing bicarbonate of soda with the flour, and then baking the mass up with buttermilk; the acid of the milk displaces the CO_2. *Unfermented bread* is made by mixing 320 grs. of bicarbonate of soda with 4lbs. of flour, dissolving 300 grains of common salt in 35 ounces of water, and adding to it 6½ fluid ounces of hydrochloric acid, and mixing up intimately, and then heating in the oven. (See *Experimental Researches*, p. 183.) Gingerbread and light cakes are often raised by means of carbonate of ammonia, which is converted into a gas by the heat.

Ether, Oxide of ethyle, Sulphuric ether ($C_4 H_5 O$, or EO).—This fluid is supposed to be the basis of alcohol. It is usually prepared by mixing 5 parts of alcohol of ·822 specific gravity, with 9 of sulphuric acid in a retort, and distilling; by having a tube passing through a cork in the tubulure and descending beneath the surface of the fluid, a fresh supply of alcohol can be gradually added. The distilled fluid contains alcohol and water; to remove the alcohol, it is mixed with its own bulk of water, when the alcohol dissolves in the water, and the ether swims on the surface. The ether may be deprived of all its water by distillation over caustic potash or chloride of calcium. The *theory* of the process is, that when SO_3 comes in contact with alcohol, it forms a fluid double salt, sulphate of ethyle and sulphate of water (EO SO_3, HO SO_3); and the proof of this is, that if we add to a boiling mixture of the two, carbonate of barytes, and evaporate, we get crystals of double sulphate of ethyl and sulphate of barytes (EO SO_3, Ba O SO_3), where the basic water has been replaced by the barytes. By distillation the double fluid salt is decomposed into EO and water, while the SO_3 remains. The various acids form similar double salts, which are termed *ethers*. Phosphoric acid gives 2 HO EO PO_5. *Nitrous ether* consists of EO NO_3. *Oxide of ethyle* is thus said to be the oxide of an *organic radical*.

Characters.— Colourless, limpid fluid, with a fragrant odour, and hot pungent taste; exceedingly volatile, disappearing even when poured from one vessel to another; evaporating with great rapidity when poured on the hand, and producing cold; hence it is used in cooling lotions in surgery. It is also much used in cupping, to produce a vacuum, by pouring half a tea-spoonful

into a cupping glass, agitating till it disappears, igniting it, and rapidly inverting it over the part which has been scarified by the lancets. Boils at 96°, and in vacuo at 20°. Specific gravity of vapour 2·583; specific gravity of fluid ·715 at 68°, ·724 at 54°; 1 part of ether dissolves in 10 water; it mixes with alcohol and ethereal oils in all proportions.

Experiments. — 1. When admitted to oxygen it doubles the volume of the gas, and 1 part of this expanded oxygen, if mixed with 3 parts of pure oxygen, explodes when ignited, water and carbonic acid being formed. 2. A few drops of ether let fall on a hot brick in a dark room, produce a luminous appearance. 3. *Flameless lamp.* — If very thin platinum wire be formed into a coil, by winding it round a thin glass rod, and be then adjusted so as to inclose the cotton wick of a lamp containing ether; if the wick be ignited, and blown out after the lapse of a minute, the wire will continue red hot as long as the ether lasts. The products of this action are acetic, formic, and aldehydic acids, possessing a very acrid odour. 4. When ether is passed through a red-hot glass tube, it is converted into aldehyde, olefiant gas, and carburetted hydrogen ($C H_2$). *Tests of purity.* — Ether should be neutral to test paper; it should not become milky when mixed with water, and should not diminish in bulk when its own volume of water is added to it. It is used as an antispasmodic in asthma, in doses of half a tea-spoonful mixed with water. It is also employed to produce insensibility in operations. It acts, when a drachm of it is placed in a bladder, and breathed, exactly like laughing gas.

Acetous or *Vinegar Fermentation.* — When wine and beer are carefully corked up they may be preserved without injury for many years; but if they are imperfectly corked, or are exposed to the air, they speedily become sour by the formation of vinegar or acetic acid: hence oxygen obviously takes an active part in this change. Pure spirit never becomes sour by exposure to the air; the presence of albuminous matter is necessary. It has been also observed that when alcoholic vapour is brought in contact with spongy platinum and air, acetic acid is produced, the metal becoming red-hot. The change is simple: —

1 alcohol and 4 oxygen = $C_4H_5O + HO$ and O_4

become

1 hydrous acetic acid and 2 water = $C_4H_3O_3 + HO$ and $2HO$.

Two atoms of hydrogen have thus been removed from the alcohol, and 2O added; while the H_2 have united with O_2 from the atmosphere, and formed water. This action is said to be by *replacement;* and the formula of acetic acid may be written $\frac{C_4H_3O}{O_2} + HO$. It would appear, however, that acetic acid is not formed at once, but that there is an intermediate stage, the pro-

duction of *aldehyde*, while the H_2 are removed and have not been succeeded by the oxygen; its formula is C_4H_3O, HO. It is a colourless, highly fluid liquid, with a very peculiar smell. Specific gravity ·79; boiling point 71½°; mixes with water, alcohol, and ether; neutral, combustible. It may be formed by dropping a few crystals of chromic acid into alcohol, as described under chromium, or by distilling alcohol, bichromate of potash, or black oxide of manganese, and sulphuric acid. It is obtained purest by uniting it with ammonia, and distilling the compound with SO_3. When kept at 32° it changes into crystals, *elaldehyde*; when retained at the ordinary temperature, *metaldehyde*, in colourless needles, appears. *Chloral* (C_4Cl_3O HO) formed by the action of chlorine upon alcohol. Oily fluid. Spec. grav. 1·5.

Experiments. — If we add a few drops of aldehyde to water in a tube, some solution of nitrate of silver, and a little ammonia to precipitate the oxide, and boil, the metallic silver is deposited on the inside of the tube, giving it a fine brilliant silvery appearance. The whole of the silver is not reduced; one half of it remains united to *aldehydic acid* $C_4H_3O_2$ (by the action of C_4H_3O and 2AgO becoming $C_4H_3O_2$ AgO, and Ag. Several other bodies possess this power of reduction; and a patent exists for silvering looking-glasses by the use of certain oils. When aldehyde is heated with potash or ammonia, the *resin* of aldehyde is obtained. When NH_3 dry, is passed into aldehyde crystals of ammonia-aldehyde separate, and if a current of SH be passed through these crystals in solution, crystals of *Thialdine*, ($C_{12}H_{13}NS_4$), a base appear which, when heated with slaked lime, yield *leucol* or *leucoline*, one of the bases of coal tar. *Acetal* ($C_8H_9O_3$) by spongy Pt on alcohol.

Acetic Acid, Vinegar, Pyroligneous Acid, Wood Vinegar ($C_4H_3O_3HO$, 7·5), may be obtained pure and strong by distilling acetate of lead, copper, or soda, with SO_3. It is a clear, colourless fluid, and crystallizes at 45° in flat plates, with a sp. grav. of 1·063; taste very sour; blisters the skin; it unites with various proportions of water, and forms vinegar of different degrees of strength. 1. *Malt Vinegar* is made by mashing malted barley with water at 170°, fermenting, placing the liquor in casks, leaving the bungs out; in two or three months the vinegar is formed. 2. *Wine Vinegar* is formed by mixing the wine to be acidified with vinegar already formed in casks supplied with apertures for the admission of air. 3. *Spirit Vinegar*, or *Quick Vinegar Method*, is executed by filling a cask with beech wood shavings, moistened with strong vinegar. A mixture of 1 part of spirits (sp. grav. ·843), 5 water, and 1 thousandth part of yeast or honey, is allowed to drop continuously through the cask; the temperature rises to 100°, and the whole of the spirit is in 24 to 36 hours converted into acetic acid, by passing two or three times through the shavings. The

cask is perforated so as to admit air, and the vinegar trickles out at the bottom. The presence of certain substances, as aromatics, fluid oils, and pyroligneous acid, prevent the conversion of alcohol into vinegar. 4. *Cider Vinegar* is made in America from refuse cider. 5. *Sugar Vinegar*, made by exposing for a summer a mixture of 20 lbs. sugar, 16 water, and 24 pints bruised gooseberries, and some yeast and raisins. 6. *Pyroligneous Acid, Wood Vinegar*, is obtained by distilling the harder kinds of wood, as oak, birch, &c. in iron cylinders, the acetic acid being afforded in largest quantity by the ligneous matter and not by the cellulin. The wood affords from 800 lbs., 160 lbs. of charcoal, 300 vinegar, and 340 of gases. The distillation lasts 8 hours. The acid liquor is separated by gravity from the oils, and is again distilled, and is saturated with lime or soda; the acetate thus formed is finally distilled with sulphuric acid. Wood vinegar retains a small portion of creasote and other oils, which render it valuable for preserving meat and vegetable substances.

Acetates are generally soluble in water, with the exception of the acetates of molybdenum and tungsten. Some of them are very important — as the *acetate of copper* or verdigris; *Acetate of alumina*, a valuable mordant; *acetate of lead*, or sugar of lead, used in medicine and the arts; *Acetate of ammonia*, or spirit of Mindererus, used to promote sweating.

Tests for acetates. — Add to a few drops of perchloride of iron so much water as to form a colourless solution. The addition of an acetate renders it yellow; SO_3 when added to an acetate evolves the smell of vinegar.

Chloracetic acid $C_4\ Cl_3\ O_3$, colourless needles obtained by the action of Cl upon strong acetic acid in the sun's rays; formed on the same model with acetic acid.

Ethionic and *Isethionic acids* are obtained by treating alcohol with solid sulphuric acid.

Acetone, Pyroacetic spirit, Naphtha, $C_3\ H_3\ O$. — A colourless fluid, with an ethereal odour; sp. grav. ·79, of vapour 2·022; obtained by distilling acetate of lead (Beecher and Proust) or acetate of lime, the action being ($CaO\ C_4\ H_3\ O_3$ become $CaO\ CO_2$ and $C_3\ H_3\ O$) due to the formation of carbonate of lime and acetone. It has been used in the treatment of consumption, but not with any benefit. It is supposed to be analogous to alcohol in its nature, or the hydrous oxide of an organic radical Mesityle ($C_6\ H_5\ O$). *Mesitylene* ($C_6\ H_4$), obtained by treating acetone with fuming $S\ O_3$. *Chloride of mesityle* ($C_6\ H_5\ Cl$), obtained by treating acetone with chloride of phosphorus. When this fluid is distilled with KO it is converted into *oxide of mesityle* ($C_6\ H_5\ O$).

Cacodyle ($C_4\ H_6\ As,\ Kd$) a colourless fluid, obtained by distilling chloride of cacodyle with metallic zinc. *Oxide of*

cacodyle, alcarsin, fuming liquor of Cadet (C_4 H_6 AsO, or Kd O), an ethereal, colourless fluid, boiling at 302°, and becoming solid at —9½°; disagreeable penetrating odour; density of vapour 7·55; obtained by distilling equal weights of acetate of potash or soda and arsenious acid; CO_2 is given out. It is highly poisonous, and takes fire spontaneously in air. It is formed by subtracting 2 CO_2 from 2 atoms of acetone and 1 arsenious acid (C_6 H_6 O_2 As O_3 less 2 CO_2 = C_4 H_6 As O). *Cacodylic acid* (C_4 H_6 As O_3 HO), formed by the slow action of air upon oxide of Kd, when the latter is placed under water; occurs in colourless crystals without smell; unites with alkalies. *Chloride of cacodyle* (C_4 H_6 As Cl), colourless fluid, obtained by digesting the *oxide* with H Cl.

Amyle hydrous oxide of, oil of grain, fuseloil, oil of whisky, potatoe oil (C_{10} H_{11} O HO). — This oil comes over in the distillation of the infusion of barley, oats, and potatoes, mixed with alcohol and water, and is purified by washing it with water, and distilling over chloride of calcium. It is a colourless oily fluid, with a peculiar, strong, penetrating odour, perceptible in the chest; burns with a white flame, and is poisonous; hence it should be entirely removed from spirits, otherwise they must be prejudicial. Spec. grav. ·812. Boiling point 269½°; spec. grav. of vapour 3147; mixes in all proportions with water and alcohol. *Chloride of amyle* (Ayl Cl). — Colourless fluid, obtained by distilling grain oil, and perchloride of phosphorus. *Sulphate of amyle and barytes* (Ayl SO_3 BaO SO_3), obtained by boiling the oil with SO_3, and saturating with carbonate of barytes: it crystallizes in pearly scales. From the existence of this salt, it was at once concluded that the oil of grain is an alcohol — that is, the hydrous oxide of an organic radical, — and it was found that it forms a series of analogous compounds to those of alcohol. All the organic radicals have a peculiar acid derived from them. Alcohol has acetic acid; formyle, formic acid; and amyle has *valerianic acid* (*delphinic acid, amylic acid*) (C_{10} H_9 O_3 HO), originally obtained from valerian root, but easily formed from grain oil by distilling it, at 400°, with a mixture of equal parts of hydrate of potash or soda and quicklime; hydrogen is set free, and valerianate of amyle remains in the retort; by distillation with SO_3 the valerianic acid comes over — a colourless oil swimming on water, sp. grav. ·937., of vapour 3·660. It occurs in the berries of the Guelder rose. *Amilene* (C_{10} H_{10}), a colourless fluid, is formed by distilling grain oil with anhydrous phosphoric acid. *Chlorovalerisic acid* (C_{10} H_7 Cl_3 O_4), thick fluid, without odour, formed by acting on valerianic acid with chlorine in the dark. The Cl replaces 3 atoms of H. *Chlorovalerosic acid* (C_{10} H_5 Cl_4 O_3), produced by Cl acting in sun-light. *Chloramilal* (C_{20} H_{17} Cl_3 O_4) an oil boiling at 356°, formed by saturating hydrate of amyle with Cl.

IV. — Other Secretions of Plants and allied Bodies.

Additional Organic Radicals mostly derived from the Secretions of Plants.

Benzoyle Series. — The compounds now to be described are all connected with the oil of bitter almonds, a substance much employed for seasoning in cookery; and it is interesting in organic chemistry, as constituting the first body from which the theory of organic radicals was deduced by Liebig. The basis of the series is a hypothetic body, *benzoyle* ($C_{14}H_5O_2$), and is supposed to exist because we can obtain an oxide of such a base ($C_{14}H_5O_2O$), and a chloride by replacing the oxygen ($C_{14}H_5O_2Cl$). *Hydret of benzoyle, oil of bitter almonds*, ($C_{14}H_6O_2$ or $C_{14}H_5O_2+H$ or BzH), obtained from bitter almonds by distillation. The almonds are bruised and strongly pressed; a yellow oil separates, destitute of smell. The expressed cake is cut into pieces and made into a paste with *cold* water, and in 24 hours the mixture distilled; a heavy oil collects in the receiver, over which swims water containing hydrocyanic acid (prussic acid), to be separated by redistillation with red oxide of mercury; percyanide of mercury remains in the retort. *Characters.* — Colourless, limpid, smell strong and peculiar, specific gravity 1·043; boiling point 324°, soluble in 30 parts of water; mixes with alcohol and ether; not poisonous; burns with much light and smoke; passes through ignited tubes without decomposition; exposed to the air it unites with 2 atoms oxygen, and is converted into *benzoic acid* ($C_{14}H_6O_4$); an alcoholic solution of the oil when heated with KO, yields benzoate of potash and a new oil; Cl and Br convert it into BzCl and BzBr, hydrochloric and hydrobromic acids being formed. *Theory.* — The formation of the oil depends upon the actions of two bodies existing in the almonds upon each other — *amygdalin*, and *emulsin* or synaptase, which are prevented from coming in contact by the fat oil at first expressed; hence, as soon as this oil is removed the reaction occurs. *Amygdalin* $C_{40}NH_{27}O_{11}$, a substance in pearly scales when crystallized from alcohol or in short needles dissolving readily in water, insoluble in cold alcohol, not acted on by dry chlorine. By NO_5 resolved into NH_3, oil of benzoyle, benzoic acid, formic acid, and CO_2; and by KO into *amygdalic acid*. Amygdalin is procured from the almond cake after expressing the fat oil by boiling with alcohol, of specific gravity ·812; the spirit is distilled off by the water-bath, the syrupy residue diluted with water, and fermented with yeast to remove the sugar; the liquor is then concentrated to the consistence of syrup and mixed with alcohol of about ·812 sp. grav., when the amygdalin falls as a crystalline powder. *Emulsin, synaptase, legumin*, obtained by making an emulsion of sweet almonds with water, adding ether to take up the oil, and precipitating the clear liquor by alcohol; or by treating the expressed sweet almond cake with cold water, precipitating the albumen by acetic acid, the gum by disacetate of lead, and the synaptase by alcohol. It is a white tasteless powder. It is a remarkable body: in contact with *salicine* producing *grape* sugar and *saligenine*, apparently by force of contact or fermentation; and with amygdalin it forms oil of bitter almonds and prussic acid, at the expense of the amygdalin and some emulsin — $C_{40}NH_{27}O_{11}$ (amygdalin) becoming C_2NH (hydrocyanic acid), $C_{28}H_{12}O_4$ (2 oil of bitter almonds), and a new body $C_{10}H_{14}O_{18}$, from which, by decomposition, sugar is formed, and perhaps formic acid. In consequence of the production of a definite quantity of prussic acid in this process, it may be employed to prepare this acid as a medicine. *Process.* — Mix 34 grains amygdaline with 66 grains emulsion of sweet almonds, so as to produce 100 grains of a mixture containing 2 grains hydrocyanic acid, (½ grain amygdalin, corresponding to 1 grain of medicinal acid); the solution of 1 grain of amygdalin in 3 ounces of emulsion of sweet almonds, contains, therefore, 1 grain medicinal acid for every ounce of mixture. *Benzoic acid* ($C_{14}H_5O_3HO$) can be obtained by the oxidation of bitter almond oil, or

by heating gum benzoin in an iron pot or porcelain bason. A cover of filtering paper is pasted over the mouth of the vessel, into which has been introduced powdered benzoin, and over the whole is pasted a paper cap, and heat is applied cautiously for some hours. The acid sublimes through the cover into the cap. *Characters.* — White pearly plates or 6-sided needles, tasteless; when heated it smells of benzoin; reaction acid; fuses at 248°, and sublimes at 290°; specific gravity of vapour 4·27; dissolves in strong SO_3, and is reprecipitated by water; dissolves in 200 cold, 25 boiling water. *Benzoate* of ammonia, formed by saturating the acid with carbonate of ammonia; crystallizes in feathery needles, and is used to precipitate iron from manganese; it is also introduced into some of the preparations of opium. *Formo-benzoic acid* $C_{16}H_7O_5$, is obtained by dissolving oil of bitter almonds in water, and evaporating with hydrochloric acid; sal-ammoniac being formed, and a yellow crystalline acid body in scales, soluble in alcohol and ether, decomposing by heat into oil of bitter almonds and hydrocyanic acid, of which two substances it consists. *Benzoate of bitter almonds* ($C_{42}H_{18}O_9$), 4-sided prisms, formed by passing Cl through the oil. *Hydrobenzamide* ($C_{42}H_{18}N_2$), in octohedral crystals, by pouring 20 NH_3 on 1 part of the oil, and digesting at 110° for 24 hours; it is insoluble in HO. *Amarine* ($C_{42}H_{18}N_2$), obtained by boiling the preceding body with KO. *Benzostilbine* ($C_{31}H_{11}O_2$), white crystals, by acting on hydrobenzamide with fused potash. When hydrobenzamide is distilled it yields silky needles. *Lophin* ($C_{46}H_{16}N_2$). By distilling the oil of bitter almonds frequently we obtain *benzimide*, colourless needles ($C_{28}H_{11}NO_4$), and when sulphohydret of ammonia is added to a solution of the oil in alcohol, a starch-like powder falls, which is *hydret of sulphobenzoyle* ($C_{14}H_6S_2$); this, when distilled, gives, first *stilbene* ($C_{28}H_{12}$), and afterwards *thionessale* in needles ($C_{28}H_9S$); chlorine, bromine, and NO_5, act upon stilbene by substitution, these bodies replacing hydrogen. If we add to bitter almond oil, containing hydrocyanic acid, an equal volume of alcohol in which caustic potash is dissolved, yellow crystals subside of *benzoin* ($C_{28}H_{12}O_4$), which is converted by boiling with potash into *benzilic acid*, and into *benzoinamide* (white needles) by standing in contact with NH_3 for some months; into *benzil* ($C_{28}H_{10}O_4$), by passing chlorine over it in a fused state; the Cl removes hydrogen without substitution. *Hippuric acid* ($C_{18}H_8NO_5HO$) is intimately allied to this series since it may be procured in human urine in large quantities by taking benzoic acid internally. It exists, however, in the natural state in human urine, and in that of the cow and horse. It may be obtained by carefully evaporating the urine of the cow, and adding HCl so as to produce a feeble acid reaction. Impure crystals of hippuric acid are deposited, and may be purified by passing Cl through a boiling solution. It is to the presence of a small portion of this acid in a free state that the acidity of urine has been attributed. *Action of agents on benzoic acid.* — *Benzole* ($C_{12}H_6$), *bicarburet of hydrogen* of Faraday, obtained among the oils from condensed oil gas, and by distilling benzoic acid with hydrate of lime ($C_{14}H_6O_4$ and 2 CaO, giving $C_{12}H_6$ and $2(CaO\,CO_2)$, or passing the vapour of this acid through a red hot gun barrel. A clear colourless ethereal fluid, solidifying at 32°, boiling at 186°. When all the benzole has been distilled, an oil *benzone* comes over ($C_{13}H_5O$) with *naphthaline*. Chlorine unites with benzole when they are exposed in a large flask to the sun, and forms *chlorobenzole* ($C_{12}H_5Cl_6$) in white crystals, melting at 270°, insoluble in water. When this substance is distilled it affords *chlorobenzide*, $C_{12}\frac{H_3}{Cl_3}$, an oily, colourless fluid, boiling at 410°. Nitric acid acts upon benzole by giving out oxygen and hyponitric acid, replacing hydrogen and forming *nitro-benzide*, $C_{12}\frac{H_5}{NO_4}$, a yellow oil, boiling point 415°, specific gravity 1·209, of vapour 4·294. *Binitrobenzide*, $C_{12}\,2\frac{H^4}{NO^4}$, may be obtained by treating benzole with SO_3 and NO_5. If we dissolve nitrobenzide in alcohol, saturate the solution with NH_3 and pass a current of SH through the deep red mixture and allow it to stand, sulphur drops; the SH is again passed, HCl added in excess; by evaporation a clear fluid remains, *Aniline* ($C_{12}H_7N$), obviously produced by the separation of all the oxygen by means of SH_2, and the place of the oxygen supplied by H from the gas. This substance is likewise obtained from coal-tar, and indigo, and is recognised by giving a

fine violet blue with solutions of chloride of lime. When the binitrobenzide, dissolved in alcohol, is treated with sulphohydret of ammonia, *nitraniline*, $C_{12}\frac{H_6}{NO_4}N$, is obtained in yellow needles. When nitrobenzide is distilled with KO, crystals come over of *azobenzide* ($C_{12}H_5N$). Sulphuric acid gives out an atom of oxygen to 1 of H in benzole when in contact with it, and forms an atom of water, while *sulphobenzide* ($C_{12}H_5SO_2$) remains in crystals. By filtering off the acid liquid from this process, saturating with carbonate of barytes, we obtain *hyposulphobenzidic acid*, $C_{12}\frac{H_5}{SO_2}SO_3$, united with barytes, and by adding sulphate of copper we obtain the copper salt in crystals. *Benzonitrile* ($C_{14}H_5N$), a clear fluid oil, obtained by distilling benzoate of ammonia. *Parabenzoyle* ($C_{14}H_5O_2$), obtained, by distilling benzoate of copper, in long white needles.

Salicyle Series. — *Salicine* ($C_{26}H_{18}O_{14}$), a neutral bitter substance in white needles, is extracted from different species of willow, and used sometimes in medicine as a substitute for quinin, fusing at 248°, dissolving in 5¼ parts of cold water, in SO_3 with a blood red colour (rutilin). The fresh bark is boiled in an iron pan with water, and exhausted; the decoction is concentrated; the gum, tannic acid, and extract precipitated by acetate of lead, and filtered; the excess of lead removed from the filtered liquor by SO_3 and Ba S; filtered, and the salicine crystallized. *Saliretin* ($C_{14}H_6O_2$), a resinous-like body, is obtained by boiling salicine with HCl or SO_3. The salicine is decomposed into grape sugar and saliretin. Chlorine in the cold state produces *chlorosalicine* ($C_{26}H_{17}ClO_{14}$), a yellow powder, and at 140° a red oil ($C_{26}H_{16}Cl_2O_{14}$). When 1 salicine is distilled with 1 bichromate of potash, 2½ SO_3, and 20 water, a clear oil comes over, which also exists in meadow sweet (spiræa ulmaria), termed *salicylous acid* or *hydrospiroilic acid* ($C_{14}H_5O_4H$), supposed to be a compound of *salicyle* and hydrogen; specific gravity 1·173, of vapour 4·276, gives a violet colour with persalts of iron, and forms *salicylites*. With NH_3 it forms *salicylimide* ($C_{28}H_{18}O_6N_2$), yellowish white needles. When mixed with ammoniacal acetate of copper *salicilimide of copper* ($C_{14}H_6NO_3Cu$), in brilliant green plates, forms. *Salicylic acid* ($C_{14}H_5O_5HO$) resembling benzoic acid, is obtained by treating salicylous acid by potash. *Chlorosalicylic acid* ($C_{14}H_5O_4Cl$), in oblique rhomboids, obtained by passing dry Cl through dry salicylous acid. *Chlorosalicylimide* ($C_{42}H_{13}Cl_3O_6N_2$), a yellow mass, formed by passing NH_3 gas into the previous acid. By NO_5 salicylous acid is converted into *nitrosalicylic acid* ($C_{14}H_5O_8N$), in small prisms, dying the cutis yellow, and forming a blood colour with NH_3. *Carbolic acid* ($C_{12}H_5O_2$), an oil resembling creasote, and found also in coal oils, is obtained by distilling salicylic acid with glass powder. *Helicine* ($C_{26}H_{16}O_{14}$) crystals obtained by digesting salicine with weak NO_5. When salicine is exposed along with emulsin or synaptase to a heat of 104° pearly crystals, separate of *saligenin* ($C_{14}H_8O_4$), forming an indigo blue colour with sesquioxide of iron salts, while grape sugar remains in solution. It is scarcely correct to say even that salicine consists of these two principles any more than it would be to consider sugar as composed of alcohol and CO_2. *Phloridzin* ($C_{42}H_{29}O_{24}$), silky prisms with a square base, a substance closely allied to salicine, is obtained from the bark of the root of the apple, pear, plum, and cherry trees, by alcohol; specific gravity 1·43; soluble in 1000 parts of water; loses 4 atoms of water at 212°. *Phloretin* ($C_{30}H_{15}O_{10}$), crystalline powder, formed along with grape sugar by boiling phloridzin with any acid except NO_5 and CrO_3. *Nitrophloretic acid* $C_{30}H_{12}O_{15}N$ brown powder, obtained by acting on phloridzin with NO_5. *Phloridzein* $C_{42}H_{29}O_{26}N_2$, a red body, formed by acting on moist phloridzin with NH_3.

Cinnamyl Series. — *Cinnamyl* ($C_{18}H_7O_2$) is the hypothetic radical of this series. Oil of cinnamon obtained by distilling the bark of the *laurus cinnamomum*, is a yellow oil, consisting of $C_{18}H_8O_2$; converted, by exposure to the air, and absorption of oxygen into *cinnamic acid* ($C_{18}H_7O_3HO$) in tufted crystals; this substance is also formed by dissolving the balsam of Peru in an alcoholic solution of potash, evaporating, dissolving the potash salt in water, and removing the potash by HCl. This acid unites with 1 atom of base. By acting on cinnamic acid with strong NO_5 *nitrocinnamic acid* ($C_{18}H_6O_3NO_4HO$), in crystals, is formed. *Nitrate of hydrate of cinnamyle*

($C_{16}H_6O_3NO_5HO$), oblique rhombs, formed by treating the oil with strong and colourless NO_5. *Hydrate of cinnamyle* ($C_{18}H_8O_2$), an oil obtained by adding water to the previous compound. *Chlorocinnose*, $C_{18}\frac{H_4}{Cl_4}O_2$, a volatile solid, the product of the action of chlorine upon the oil. *Oil of Peruvian balsam or cinnamein* ($C_{72}H_{32}\frac{1}{2}O_{10}$), obtained by treating 1 measure of balsam of Peru with 1½ caustic potash; it swims on the surface of a dark saccharine solution; when boiled with alkalies it is changed into a colourless oil, *peruvine* ($C_{18}H_{12}\frac{1}{2}O_2$), and cinnamic acid. *Balsam of tolu* is divided into two oils by alcohol of ·856 specific gravity. *Myriospermin* is soluble in that fluid, and by potash is converted into *myriospermic acid*. *Myroxilin*, of specific 1·111, insoluble; by potash it is converted into cinnamic acid and resin. *Styrole* ($C_{16}H_8$) an oil from Storax probably applied to this series. *Cumyl* is the hypothetic basis of oil of cumin, an oil extracted from the seeds of the *cuminum cyminum*. The oil is colourless, boils at 428°, and by oxidation is converted into cuminic acid. By potash it is changed into *cumene*. *Anisyle*, the hypothetic base of the oil of anise ($C_{20}H_{12}O_2$). *Guiacyle* the radical of guaiac resin. *Allyle*, the base of the oils found in garlic, assafœtida, mustard, or *sulphuret of allyle* (C_6H_5S)

Glyceryle is the hypothetic basis of oils which occur both in plants and animals. When we boil olive oil with oxide of lead and water, the acid (oleic acid) of the oil unites with the lead, forming a lead soap, while the oxide of glyceryle united with water $C_6H_7O_5HO$, is set free and dissolves in the water. The water is poured off and evaporated in vacuo, when *hydrate of the oxide of glyceryle*, or *glycerin, the sweet principle of oils*, remains. It is a colourless oil of 1·25 specific gravity; mixes with water and alcohol in all proportions; taste sweet, and hence its name; insoluble in ether. The same body constitutes the basis of all oils, which are merely compounds of glyceryle, united, with an acid. *Bisulphate of glyceryle oxide* ($C_6H_7O_6HO\,2SO_3$), an acid fluid, obtained by treating the hydrate with SO_3, and it is formed when all oils are brought in contact with the same acid.

Acryle (C_6H_3) is the hypothetic base derived from the distillation of glycerine, and to which the disagreeable odour perceptible on blowing out a candle is owing. *Acrolein* or *hydrous oxide of acryle* (C_6H_3O+HO), a colourless liquid, with a disagreeable smell acting on the eyes and nose; taste acrid and caustic; swims in water. *Acrylic acid* ($C_6H_3O_3+HO$), obtained by distilling fats and rectifying the products over CaCl, and then distilling with AgO. Acrylate of silver is formed, and may be crystallised out of water.

Cetyle ($C_{32}H_{33}$) is the hypothetic base of spermaceti, a crystalline fatty matter extracted from a species of whale. When this substance is boiled with potash or soda and water for some days a soap is produced which decomposes with an acid into a mixture of margaric acid, oleic acid, and *ethal*, or *hydrate of oxide of cetyle* ($C_{32}H_{33}OHO$), which may be separated from the acids by boiling with barytes water. Oleate and margarate of barytes remain insoluble, while *ethal* may be dissolved in cold alcohol and purified by ether. It is a white, firm, crystalline mass, with a pearly lustre, without taste or smell. *Chloride of cetyle* $C_{32}H_{33}Cl$, an oil obtained by the action of chloride of phosphorus upon ethal. *Cetene* $C_{32}H_{32}$, a colourless oily fluid, formed by distilling ethal with phosphoric acid; specific gravity of vapour 7·84.

Theory of orgahic or compound radicals or bases.—The preceding bodies have been termed organic radicals, from the circumstance of each forming the base or root of a series of compounds. It has been objected to the admission of these radicals, that most of them are hypothetic, and that they have never been isolated. The answer to this objection is, however, that two of them, viz., *cacodyle* and *methyl*, have been set free from their combinations; and that, by such a process of reasoning, the existence of nitric acid, which has never been freed from a base, of the compound acids of sulphur and of many vegetable acids and other bodies, might be denied. At the same time it must be admitted that until the demonstration of their existence is produced, scepticism is fully admissible, and may lead to inquiries respecting the true nature of the compounds into which these radicals enter as constituents.

Vegetable Alkaloids secreted by Plants.

These substances, of great importance in medicine, are obtained from various parts of different kinds of plants, as the bark, seeds, and roots. They exist in the plant in union with an acid, forming an uncrystallizable salt, which, in its taste and physiological influence, is characteristic of the base itself. The theory of the process for extracting these bases from the plant is to procure them in solution in water, if possible; this is usually effected by boiling with water, and at the same time by mixing the water with a mineral acid which displaces the native weaker acid, and unites with the alkaloid. The new salt, consisting, for example, of sulphuric acid and the base, is soluble in water, and is then to be purified. The first of this numerous class of bodies was discovered in 1804, by Sertürner. Five of these bodies are fluid oils, the remainder solids, and generally crystallizable. 13 alkaloids are precipitated white by infusion of nut-galls, viz. coniin, quinin, cinchonin, morphin, codein, narcotin, delphinin, strychnin, brucin, emetin, atropin, aconitin, veratrin.

Oily Alkaloids.

Nicotin (C 73·26 H 9·65 N 17·09). — Obtained by distilling a solution of nicotin in ether. To prepare this, the tobacco leaf or seed is boiled with a mineral acid diluted, mixed with KO, and the oil distilled over with NH_3. The distilled fluid is saturated with oxalic acid, or SO_3, evaporated to dryness, and digested in cold alcohol; the ammoniacal salt remains, while the oxalate of nicotin dissolves. The alcohol is evaporated; the residue placed in a close vessel, and mixed with half its volume of strong KO, and then with an equal volume of ether. The potash separates the base, which is dissolved in the ether; by distillation, the NH_3 and ether pass over, the base remaining; it may then be purified by distillation in a water bath. *Characters.* — A colourless oil, with a faint smell of tobacco, boils at 475°, and decomposes; specific gravity 1·048; restores the blue colour of red litmus; very poisonous, a quarter of a drop killing a rabbit. It unites with acids, and forms salts.

Coniin. (C 66·91 H 12· N 12·81 O 8·28). — Colourless oily fluid, specific gravity 0·89; 1 part dissolves in 100 parts of cold water, imparting a strong alkaline reaction; dissolves in all proportions in alcohol; very poisonous; unites with acids forming salts. *Anilin* (p. 180). — *Picoline* $C_{12}H_3N$ (*Anderson*), an oily base isomeric with anilin obtained from coal tar. *Leucoline* $C_{18}H_8N$, an oily base, also existing in coal tar, and obtained by distilling quinin with potash.

Solid Alkaloids.

Quinin (C 74·37 H 7·30 N 8·6 O 9·75).—Formula, $C_{20} H_{12} NO_2$. Fine silky needles or white powder, soluble in absolute alcohol, and in acids, from which it may be separated and precipitated by alkalies; non-conductor of electricity; bitter taste; melts by heat into an oily fluid; slightly soluble in water, requiring 400 parts at 60°, and 250 at 212°. The solution is alkaline; iodine in alcohol renders it brown. When a solution of chlorine in water is added to quinin, and then NH_3, a fine *deep green* colour is produced, which is a *characteristic test.*

Process.— Quinin is obtained from the Peruvian bark. 1. The bark is finely pounded, digested for 36 hours at about 150°, with 4 times its weight of water, containing one-fiftieth of SO_3, filtered through a cloth, and pressed. It is again heated with acid water till the bitter taste is removed from it. 2. The washings are concentrated by gentle heat, the concentrated fluid exposed to the air for some days and filtered. 3. To the filtered liquor is added carbonate of soda in solution as long as a precipitate falls. The carbonate dissolves colouring matter, and throws down the quinin. The quinin is thrown on a cloth, and washed with a small quantity of water, dried, and dissolved in alcohol of specific gravity ·830. If discoloured, animal charcoal may be added. Quinin may be detected in bark by Cl and NH_3 test.

Disulphate of quinin (2 quinin, SO_3 + 8 HO).— This important salt in medicine may be obtained by dissolving the quinin in SO_3, as obtained in the preceding process, before the addition of the alcohol. *Characters.* — Fine white silky needles, very bitter; in dry air it loses 10½ per cent. of its weight; 1 part is soluble in 740 of cold water and in 30 of hot water, and in 60 of alcohol (·85 specific gravity). When acid is added to the preceding salt, the neutral sulphate is formed, which crystallizes in 4-sided prisms; is very soluble in water — hence, when the disulphate is ordered in medicine, a few drops of SO_3 or H Cl are directed to be added to the prescription — *Quinoidin* is an isomeric form of quinin.

Cinchonin (C 78·18 H 7·66 N 9·05 O 5·1).— Form $C_{20} H_{12} NO$. Colourless 4-sided prisms or needles, bitter taste; loses no water in dry air, and sublimes by heat; soluble in 2500 parts of boiling water, not in cold; SO_3 colours it brown; combines with acids and forms crystalline salts.

Aricin (C71 H7 N8 O14) — Occurs in the bark of arica; it consists of white needles, separated by the same process as quinin; strong NO_5 renders it green; it is insoluble in HO, but more soluble in alcohol and ether than cinchonin. The salts are bitter, insoluble in ether. The three preceding bases

are considered to be oxides of one and the same base. If we call the hypothetic base, *Cinchonyle* ($C_{20} H_{12} N$), then cinchonin is $C_{20} H_{12} NO$, quinin $C_{20} H_{12} NO_2$, and aricin $C_{20} H_{12} NO_3$.

Morphin (C 72·28 H 6·74 N 4·8 O 16·18.) Form. ($C_{35} H_{20} NO_6$), white pearly rectangular prisms; taste bitter; by heat it loses its lustre and water; 1 part dissolves in 500 of boiling water; cold water and alcohol have little action. But alcohol of ·830 dissolves it in the proportion of 1 morphin to 24; insoluble in ether and ethereal oils; soluble in alkalies. *Process.* — Morphin exists in opium united to meconic acid. The process consists in dissolving the salt in water, and taking up the morphin by lime and combining the meconic acid with lime. 1. The raw opium is cut into pieces, macerated with 8 times its weight of water, and pressed through a cloth; the process repeated 3 or 4 times. 2. The concentrated solution is then mixed with a milk of lime, containing about one-fifth of opium to the lime, and boiled for a few minutes; the lime precipitates the colouring matter, other bases, and acid, and dissolves the morphin. 3. The mixture is then filtered and washed with boiling water; the liquor evaporated till it reaches *double* the weight of the opium employed, filtered through paper, boiled, and an ounce of sal-ammoniac added for each pound of opium. The muriate of morphin crystallizes out in needles. The morphin may be separated from the acid by NH_3. The *muriate* contains 6 atoms of water, 1 of base, and 1 of acid; it is bitter, and soluble in 18 parts of cold water, and in its own weight of boiling water. *Acetate* crystallizes in prisms, has a bitter taste, and may be obtained by dissolving morphin in acetic acid; very soluble in water, easily parts with a portion of its acid by keeping, and is then only partially soluble. Both of the preceding salts are used extensively in medicine as a narcotic, and frequently for criminal purposes. It is necessary, therefore, to have some *tests of distinction* for morphin. When strong NO_5 is added to a strong solution of morphin it becomes *orange red;* chloride of iron renders it *blue;* the violet solution of chameleon mineral, *green;* the solution of gold, *blue;* nut-galls, *white.* *Codein* (C 74·27 H 6·93 N 4·92 O 13·88). Form, $C_{35} H_{20} NO_5$. — Colourless octahedrons, losing 2 atoms of water at 212°: 1 part dissolves in 80 water at 60°, and in 17 at 212°; easily soluble in alcohol and ether; may be prepared by digesting the precipitate of morphin with carbonate of soda in cold alcohol, neutralizing with SO_3, evaporating the alcohol, adding water, filtering, evaporating to a syrup, and treating the residue with its own volume of potash and four times its bulk of ether. The ether leaves on evaporation *codein.* Various other bases are found in opium, viz. thebain, pseudomorphin, narcein, narcotin, which are all probably modifications produced either by the processes used, or different conditions

of the same elements, altered by circumstances and taking new arrangements. From the cheledonium majus is extracted *chelidonin*; from the glaucium luteum, *glaucin* and *glaucopicrin*.

Hyoscyamin. — Silky needles obtained from the seeds of Hyoscyamus niger by digesting in alcohol with a few drops of SO_3; to the filtered liquor caustic lime is added in excess; it is again filtered and saturated with SO_3, filtered, and the spirit distilled to one fourth. Water is added to the residue, and evaporated till the spirit is expelled; the residue is saturated with carbonate of potash and filtered. To the filtered liquid an excess of carbonate of potash is added, the mixture treated with ether, and the alkaloid purified with alcohol and animal charcoal. *Daturin*. — Colourless prisms obtained from datura stramonium by the same process as for hyoscyamin; it is highly poisonous; with acids it forms salts. *Atropin*. —White silky prisms obtained by a similar process from the atropa belladonna; it forms crystalline salts with acids. *Solanin*. — White, pearly, 4-sided prisms, obtained from the young shoots of the potatoe by treating them with dilute SO_3, boiling, and precipitating by caustic potash; washing the precipitate with NH_3 until it passes through colourless; then dissolving in boiling spirit; solanin crystallizes out. *Veratrin*. — A white or greenish white crystalline powder from the seeds of veratrum sabadilla, by a similar process to that employed for solanin. *Sabadillin* (?) — reddish or colourless 6-sided prisms soluble in boiling water, separated from the alkaline precipitate of the preceding process by boiling in water. *Colchicin*. — Colourless prisms and needles obtained from the seeds of colchicum autumnale by the same process as daturin. *Aconitin*. — White grains from the aconitum napellus, or monks-hood, by a process similar to that used for hyoscyamin. *Delphinin*. — Pale yellow substance, obtained from the delphinum staphesagria. *Emetin*. — White powder obtained from ipecacuan powder, the root of the Cephaelis ipecacuanha, by exhausting it with boiling water, and digesting the dry residue in alcohol, and distilling it off. The emetin is extracted from this by dissolving it in 4 parts of water acidulated with HCl precipitating by corrosive sublimate, dissolving in alcohol, precipitating by sulphuret of barium, filtering, precipitating the barytes by SO_3; and the emetin by caustic NH_3.

Strychnin (C 76·36 H 6·51 N 8·04 O 9·09). Form, C_{44} H_{23} N_2 O_4. — White shining regular octahedrons, or 4-sided prisms, terminated by 4-sided pyramids. Taste bitter; poisonous; soluble in 7000 cold and 2500 hot water; scarcely soluble in weak alcohol, more soluble in absolute alcohol; insoluble in ether. Obtained from the seeds of the strychnos nux vomica, in which it exists united with igasuric acid, by boiling them in water for 30 hours, containing an eighth of SO_3, filtering and pressing; the sulphuric

acid appears to convert the hard mucus (which prevents the pulverization of the seeds) into sugar, and softens the fibrous matter. An excess of caustic lime is then added to the solution, the dark solution poured off, and the precipitate pressed. It is then heated twice with alcohol of ·85, the alcohol distilled off, and the residue allowed to cool. The liquor is removed from the precipitate formed, and the latter washed with cold alcohol until it ceases to be coloured. The grayish white powder is boiled with sufficient alcohol and animal charcoal, and filtered while hot. Pure strychnin crystallizes out: it is used in paralysis. It unites with acids and forms salts. *Brucin* (C 71·11 H 6·6 N 7·5 O 14·8). Form. $C_{44} H_{25} N_2 O_7$.—White rhombic prisms, with a bitter taste; poisonous, melts by heat in its crystalline water, which amounts to 16 per cent.; requires 850 of cold and 500 boiling water to dissolve it; easily soluble in alcohol, insoluble in ether. Strong NO_5 gives it a bright red colour; SO_3 makes it rose red and then yellow. *Jervin* is found in the root of the veratrum album. *Curarin* is the poisonous principle in urara poison of S. America. *Corydalin*, in corydalis bulbosa. *Carapin*, in carapus guianensis. *Cusparin*, in bonplandia trifoliata. *Daphnin*, in some species of daphne. *Fumarin* in fumaria officinalis. *Bebeerin*, from the bebeeru tree of British Guiana, by a process similar to that for extracting quinin. It is is a brownish uncrystalline substance, forming salts with acids, especially the *disulphate* of bebeerin, which is soluble in water, and is used as a tonic and a febrifuge. (*Maclagan.*) *Sanguinarin*, from the sanguinaria canadensis root, by means of alcohol. *Azadirin*, from the melea azadirachta. *Capsicin*, obtained by alcohol from the pods of the capsicum annuum. *Crotonin*, in the seeds of the croton tiglium, or croton oil plant. *Buxin*, from the box-tree. *Apirin*, from the cocos lapidea. *Cynapin*, from the aethusa cynapium. *Castin*, from the vitex agnus castus. *Cicutin*, from the cicuta virosa. *Chærophyllin*, from chærophyllum bulbosum. *Limonin*, from lemon stones. *Esenbeckin*, from esenbeckia febrifuga. *Digitalin*, from fox-glove. *Eupatorin*, from eupatorium cannabinum. *Euphorbin*, from the resin of euphorbium. *Convolvulin*, from scammony. *Pereirin*, from the pereira bark. *Pelosin*, from the root of the pereira parva. *Oxyacanthin*, from the berberis vulgaris bark. *Surinamin*, from geoffræa Surinamensis. *Jamaicin*, from geoffræa inermis. *Berberin*, from the bark of the root of the berberis vulgaris; it is used as a tonic, and forms salts with acids. Dry chlorine renders it blood red. *Piperin* (C 72 H 6·5 N 4·9 O 16·7. Form. $C_{34} H_{19} NO_6$).—White 4-sided prisms, extracted by alcohol from the white pepper; without taste and smell; insoluble in water; neither acid nor alkaline; fuses at 212°. SO_3 converts it into a dark blood red colour, from which water again precipitates the piperin. NO_5

makes it reddish yellow; it is a weak alkaline base. *Menispermia*, white 4-sided prisms, obtained from cocculus Indicus (menispermum cocculus) after the separation of the picrotoxin, by exhausting the portion of the extract insoluble in alcohol, with acidulated water, precipitating with alkali, removing the colouring matter by some cold alcohol, and dissolving the alkaloid in ether; the menispermin crystallizes out. *Harmalin*, rhombic prisms from the seeds of the peganum harmala, by extraction with acidulated water, precipitation by potash, and extraction by alcohol. *Theobromin*, white crystalline powder from the beans of the theobroma cacao, by extraction with hot water, precipitating with acetate of lead, and evaporating the liquor freed from lead; the theobromin is taken up by alcohol from the residue. *Caffein, thein, guaranin*, (C 49·79 H 5 N 28·78 O 16·12). Form, $C_{16}H_{10}N_4O_4$.—White silky fibrous crystals, obtained from tea and coffee, by treating the hot infusion by subacetate of lead and ammonia; filtering the liquor; passing SH through it; filtering, and evaporating when the thein crystallizes out. It absorbs H Cl gas, and also combines with nitric acid. According to the most recent experiments tea leaf contains the largest amount of nutritive matter of any plant used as human food; but only a portion is extracted by the common mode of using tea. Perhaps a larger quantity of nutrition is taken up by the Tartar mode of preparing the beverage. The tea leaves are boiled with soda, which will have the effect of dissolving the casein which they contain, mixed with common salt and butter. *Cyaniline* ($C_{14}H_7N_2$), plates obtained by passing cyanogen through aniline. *Toluidine* ($C_{14}H_9N_4HO$), a solid base, obtained by acting on nitrotoluol with HN_3 and SH. *Cotarnin* and *Narcogenin* are bases derived from narcotin, while *Furfurin* $C_{30}H_{12}N_2O_6$ (Fownes), is a crystalline base obtained by acting on *furfurol*, artificial oil of ants with NH_3, and treating *furfurolamide* thus formed with potash.

Theory of Vegetable Alkaloids. — The most probable view of the nature of the alkaloids is, that they are analogous to ammonia. This parallelism has been well worked out by Dr. Hoffmann in regard to *aniline*. As they all contain N, it has been suggested by Fresenius, that they may contain NO_4 in the same state of combination as that body exists in *nitraniline* ($C_{12}H_6NO_4N$), that is, replacing an atom of hydrogen. But the facts seem scarcely reconcilable with such a limited view, since cyanogen, on uniting with aniline, forms the base cyaniline.

Extractive and Bitter Principles secreted by Plants allied to the Alkaloids.

These substances are extracted from plants, by means of water, or alcohol, or ether, and when bitter are the source of that peculiar taste imparted by the plant; they are generally neutral, uniting neither with acids nor bases. The

nature of these substances is very imperfectly understood. Many of them are soluble in water, others only in alcohol and ether. The solutions in water and alcohol become darker coloured by exposure to the air and the absorption of oxygen. When evaporated to the consistence of syrup, they are termed *extracts*, and are divisible into watery or alcoholic, according to their relations to these substances. The alcoholic extract contains all the medicinal matters. By redissolving most extracts in water or alcohol, a dark matter remains, consisting of oxidized matter, albumen, mucus, and gallic acid. It is upon a knowledge of the behaviour of these substances with reagents, that the mode of purifying bitter matters depends.

Absinthin. — From wormwood, by means of alcohol.

Amanitin. — Obtained from poisonous mushrooms.

Antiarin. — Pearly plates; from the upas antiar, extracted by alcohol; poisonous.

Arthanitin. — White needles from the root of the cyclamen Europæum.

Asparagin. — ($C_8N_2H_8O_6$) rhombic prisms from the althæa and asparagus.

Bryonin. — Yellowish white mass, from the root of the bryonia alba.

Cetrarin. — From Iceland moss (Cetraria Islandica); by boiling the lichen with absolute alcohol, the cetrarin separates in grains by distillation. It is purified by washing with cold water, ether, and weak alcohol, and crystallizing out of absolute alcohol in fine white crystalline grains.

Cornin. — From cornus florida.

Colocynthin. — Yellow matter obtained by cold water and alcohol from colocynth, cucumis colocynthus, and is the aperient principle in the medicine of that name.

Coumarin. — A base yielding the odour of woodruff, hay-grass, and tonka-beans, derived from these plants.

Cyclamin. — From Cyclamen Europæum.

Cytisin, cathartin. — Both yellowish substances, apparently the same; the first extracted by alcohol from the seeds of the cytisus laburnum, the second from the cassia senna, in which plant it acts as the aperient.

Columbin. — Colourless rhombic prisms, bitter and neutral, extracted by alcohol from columbo root; scarcely soluble in cold water spirit and ether; SO_3 make it red.

Cubebin. — White needles extracted from the marc of oil of cubebs (piper cubebas) by alcohol and precipitated by potash.

Daphnin. — Colourless crystals from the daphne mezereum.

Elaterin. — An uncrystallized principle in the momordica elaterium, much used as a powerful purgative.

Ergotin. — A brownish red matter extracted from ergot of rye by ether and alcohol.

Fraxinin. — Six-sided prisms from the bark of the ash or fraxinus excelsior, by precipitating the decoction by acetate of lead, the filtered liquor by SH, and evaporating.

Gentianin. — Golden bitter needles subliming by heat, soluble in hot water, alcohol, ether, and acetic acid, obtained from the powdered root of the gentiana lutea, by treating with ether; distilling off the greater portion, and allowing the remainder to evaporate spontaneously; the residue is digested in alcohol of ·830; the gentianin crystallizes out.

Guaiacin. — Dark yellow mass obtained by alcohol from guaicum wood.

Hesperidin. — White needles from citrons.

Juglanin. — Dark brown bitter from the walnut, juglans regia.

Imperatorin. — Colourless rhombic prisms; by ether from the root of the imperatoria ostruthium.

Lactucin. — Yellowish or reddish matter from the common lettuce and other species of lactuca; obtained from the milky juice, by alcohol.

Lapathin. — A hard bitter from rumex obtusifolius.

Liriodendrin. — Colourless scales, resembling boracic acid, from Liriodendron tulipifera.

Lupulin, bitter matter of hops. — Reddish yellow powder obtained from hops by alcohol, mixing the evaporated extract with water, saturating the aqueous solution with lime, and treating the evaporated residue with ether and alcohol.

Meconin. — Six-sided prisms obtained from an aqueous solution after precipitating morphin by N_2H_3. The meconin separates from the filtered liquor.

Menyanthin. — From the menyanthes trifoliata.

Melampyrin. — Crystals from melampyrum nemorosum.

Mudarin. — A pitchy matter obtained by water from the mudar, colotropis mudarii.

Ilicin. — Yellow crystals from holly.

Scillitin. — Colourless matter derived from the sap of the scilla maritima, or squills, by alcohol.

Narcissin. — White substance obtained by alcohol from the narcissus pseudo-narcissus.

Olivin. — White needles by alcohol from the resin of the olive tree.

Peucedanin. — White prisms obtained by alcohol from the root of the peucedanum officinale.

Phillyrin. — Amorphous mass from the phillyrea media.

Picrotoxin. (C_{12} H_7 O_3.) Poisonous, white, 4-sided prisms; bitter, decomposing at high temperatures without melting; soluble in 150 cold 25, boiling water, 3 boiling alcohol; soluble in ether; obtained from cocculus indicus by means of alcohol; the picrotoxin crystalizes out, mixed with oil which is removed by pressing between paper, redissolving in alcohol, and filtering through animal charcoal.

Picrolichenin, or *variolarin.* — Colourless octohedrons extracted by alcohol from the variolaria amara, a common lichen on trees.

Plumbagin. — Orange yellow needles, from plumbago Europæa.

Populin. — White hard needles from the populus tremula.

Porphyroxin. — Shining needles from opium by ether, water and ether. The last boiling with ether, codein, thebain, and porphyroxin. The first is precipitated by dissolving the three in HCl, and adding NH_3, Thebain and porphyroxin fall; spirit takes up the porphyroxin.

Quassin (C 66·7 H6·9 O26·3.) — Bitter small white prisms, obtained from the wood of quassia amara, by boiling the wood in chips in water, filtering, evaporating to three fourths of its bulk, throwing down pectin, &c., by slaked lime. After remaining one day in contact with the lime, the liquor is filtered and evaporated to dryness, and digested with alcohol of ·830 specific gravity. Impure crystals subside, which are further purified by absolute alcohol, ether, and evaporation. This is an important tonic in medicine.

Quercin. — Crystalline from Quercus robur (the oak) by alcohol.

Santonin. — White 6-sided prisms from chamomile and other species of artemisia.

Saponin. — White matter from the root of soapwort, saponaria officinalis, a common plant in gardens. By means of potash converted into saponic acid.

Senegin. — White substance from the polygala senega.

Smilacin. — Colourless, tasteless needles, obtained by treating the root of the smilax sarsaparilla with alcohol, and evaporation, and removing the colouring matter by animal charcoal.

Syringin. — An uncrystalline bitter from the syringa.

Tanghinin. — Crystals from Madagascar tanghin.

Xanthopicrin. — Greenish yellow needles obtained from xanthoxylum clava Herculis, by alcohol, water, and ether.

Colouring Matters secreted in Plants.

Colouring matters are diffused in all parts of plants; sometimes, as in madder, we find the colour in the roots — as in Indigo, derived from the whole plants; in saffron, in the flowers, in sapan in the wood. But the colour which we obtain from plants does not always exist ready prepared in the vegetable organism, but assumes its hue by ulterior preparation, as with litmus; some colouring matters are soluble in water, others in alcohol and ether.

The GREEN COLOURING MATTER of leaves has been termed *chlorophylle.* It has been obtained from the leaves of the cratægus aria by means of ether; the extract thus procured is treated with absolute alchohol, the solution evaporated, and H Cl added to it: it becomes of a fine emerald green, a dark coloured substance remaining undissolved. The chlorophylle is precipi-

tated by water, washed with water, and boiled, by which a small quantity of a yellow substance dissolves. It is dissolved in caustic potash, which leaves a small portion of a black substance; it is again precipitated by acetic acid. When dried it is grass green. At 390° it gives a trace of moisture; but does not fuse; it is quite insoluble in water, but somewhat soluble in alcohol; Cl bleaches it; SO_3 dissolves it, with a fine emerald colour, from which water precipitates it.

Polychrom. — Colourless bitter crystals; soluble in hot, less soluble in cold water, and in alcohol and ether. It may be obtained from the bark of the horse-chestnut and other trees, by boiling with water, precipitating by acetate of lead — the filtered liquor precipitated by SH to remove the excess of lead, and evaporated to a syrup. The polychrome crystallizes out; it is washed with cold water, and then dissolved in a mixture of alcohol and ether; it reddens litmus, but is neutral to bases and acids. A solution of it is blue by reflected light.

RED COLOURING MATTERS. — Red appears to be a favourite colour with many plants, as in the flowers of the rose, poppy, pink; it is often changed to blue by alkali, and yellow or red by acids. It may be removed by alcohol, and obtained in the form of a pink powder. The leaves and fruits of many trees assume a pink aspect in the fall of the year, due to the presence of a substance which has been called *erythrophylle*: it may be extracted by alcohol — the solution precipitated with acetate of lead. The filtered liquor is freed from lead by SH, evaporated, and a reddish brown matter obtained.

Madder supplies the fine red colour so conspicuous in Turkey-red handkerchiefs, and other products of calico printing. The best roots (of rubia tinctorum) are obtained from the Levant, although good madder is also raised in Alsace and Holland.

When 1lb. of madder roots is exhausted with 16 quarts of boiling water, and sulphuric acid added to the filtered fluid, a brown precipitate falls, which consists of six substances. It is washed with cold water, and treated with boiling alcohol, which dissolves — *Alizarin*, *Rubiacin*, *Rubian*, and two resins. Fresh alumina is added until the liquor loses its colour; the coloured alumina is filtered and washed with alcohol. It is boiled 3 times in a solution of carbonate of potash, which leaves a compound of alizarin and alumina, and dissolves the rest. This compound is boiled with HCl; a red crystalline powder remains which is *Alizarin* $C_{14}\ H_5\ O_4$. It is purified by solution in alcohol and crystallization. It is obtained in reddish yellow prisms, resembling isatin: it sublimes at 420°; soluble in ether, slightly soluble in boiling water. — *Alizaric acid* $C_{14}\ H_5\ O_7$ colourless rhombs, obtained by the action of dilute NO_5 on alizarin or commercial *garancin*. — *Rubiacin*, $C_{31}\ H_9\ O_{10}$ yellow plates and

needles, obtained by treating the brown precipitate from madder decoction with perchloride or pernitrate of iron, and adding H Cl or SO_3. — *Rubiacic acid* C_{31} H_9 O_{17} lemon-yellow powder, the result of the oxidation of rubiacin. *Rubian* is the yellow bitter principle of madder, and is obtained from the brown precipitate of madder, by washing with cold water; *Pectic* acid dissolves along with it. *Xanthin*, a brownish syrup, obtained by evaporating the decoction of madder. — Alizarin appears to be the only colouring matter in madder, according to Schunck, by whom the above facts were ascertained. There are also 2 resins in madder,

Garencin, an impure body, is obtained by SO_3 from madder.

Archil (*orseille*). — A red colouring matter from the roccella tinctoria, produced by the action of urine or carbonate of ammonia. Archil contains two colouring substances, *alpha orcein* (C_{18} H_{10} NO_6), and *beta orcein* produced from the first by oxidation, and *erythroleic acid* and *azoerythrein*. *Orcin* ($C_{18}H_{12}O_8$) in colourless 4-sided prisms, is prepared from the fresh lichen by boiling with alcohol, filtering, distilling off the spirit, exhausting the extract by water, and crystallizing. When exposed to air and NH_3 it is changed into *orcein*, or *beta orcein*, a fine red body. — *Lecanorin* (C_{18} H_8 O_8), silky colourless needles, extracted by means of ether, and changing by the action of alkalies and air into *orcin* and carbonic acid. — *Erythric acid*, *Erythrin* (C_{34} H_{19} O_{15}) snow-white scales, obtained by water and alcohol from roccella tinctoria. *Erythrylin* (C_{22} H_{16} O_6), white powder insoluble in water. Erythrin, by boiling with water, is converted into *Picroerythrin* ($C_{34}H_{24}O_{20}$) crystals, which may be separated by evaporation and solution in alcohol. *Alpha orsellic acid* ($C_{32}H_{16}O_{13}$), white needles, obtained by treating archil lichen, from South America, with milk of lime, precipitating by HCl, and crystallizing the precipitate in alcohol. *Beta orsellic acid* ($C_{34}H_{17}O_{14}$), obtained by a similar process from the Cape of Good Hope archil. *Alpha orsellesic acid* ($C_{16}H_8O_7$), crystals procured by neutralizing freshly precipitated orsellic acid with barytes water, precipitating by HCl, and crystallizing from alcohol. *Roccelline* ($C_{38}H_{17}O_{15}$), silky needles by the action of alcohol on crude orsellic acid. *Pseudo-orcine* ($C_{10}H_{13}O_{10}$), large colourless crystals from the lime solution of Roccella Montagnei, by passing CO_2 through it, and evaporating to a syrup. Ether dissolves orcine, and leaves pseudo-orcine, which may be crystallized from alcohol. — (*Stenhouse.*) Various other substances are obtained from lichens, probably, like many of the preceding, products of oxidation, &c. *Usnic acid*, C_{38} H_{17} O_{14}, sulphur crystals from lichens.

Cudbear (persio), a red matter from the lecanora tartarea by the action of gas ammoniacal liquor.

Draconin, *dragon's blood*. — Red powder, without taste and smell. Specific gravity 1·19, insoluble in water; used as a tooth

powder and for varnishes, obtained from the Dracæna drago. *Santalin.* — Fine carmine powder, obtained by alcohol from the Pterocarpus Santalinus; tasteless, insoluble in water, soluble in alcohol, ether, and acetic acid. *Brezilin, Fernambuc red, Brazil red.* — Red powder, obtained from different species of cæsalpina, by digesting the rasped wood in water, evaporating the infusion to dryness, dissolving the residue in water, agitating with litharge to remove acid, evaporating; digesting the residue in alcohol, and evaporating. The residue is brezilin; it is soluble in alcohol, and water; alkalies render it violet. Sapan and Camwoods appear to contain the same colouring matter. *Red ink* is made by digesting 50 parts of Brazil wood in 200 of vinegar for 3 days, boiling for an hour, filtering, and to the liquid are added 6 parts each of gum arabic, sugar, and alum. *Hæmatoxylin.* — Yellow 4-sided prisms, with a slight astringent taste; soluble in water, alcohol, and ether. It is often obtained in frosty weather crystallized in the preparation of logwood liquor for the printers. It is prepared by taking up an extract of logwood (Hæmatoxylon campeachianum) with water, evaporating, dissolving in ether; the ether is distilled off; the syrupy extract mixed with water, which gradually deposits crystals. H Cl colours it purple, NO_5 reddens it, isinglass precipitates it. When dried at 212° it consists of C 63·6 H 4·50 31·8. Form, C_{40} H_{17} O_{15}. When its solution is mixed with NH_3 and allowed to stand in the air, and then acetic acid is added, a rust-coloured precipitate, *hæmatein*, falls. *Ammonia-hæmatein* crystallizes out of a solution of hæmatoxylin in NH_3.

Carthamin, safflower. — From the flowers of carthamus tinctorius, by digesting them in cold water, to which some acetic acid is added; a yellow colouring matter is thus taken up. The flowers are then digested in the solution of an alkaline carbonate, which takes up the red carthamin; the addition of acetic acid precipitates it; it is insoluble in water and dilute acids, slightly soluble in alcohol. *Rouge* is formed of carthamin pounded with talc, and is extensively used as a pigment for the face, &c. *Cactin*, a scarlet powder obtained from cactus speciosus, by a mixture of alcohol and ether.

Carmine, cochineal, red crystalline grains soluble in water and alcohol, insoluble in ether. Aqueous solutions become yellowish red by acids, by alkalies violet; precipitated by alum; it is obtained by dissolving out fat from cochineal by ether; dissolving and crystallizing out of alcohol.

Blue Colours. — *Indigo* is the product of the indigofera tinctoria; the plant is cut before flowering, and placed in a vat, covered with water and allowed to steep for 9 to 12 hours, where it ferments. The yellow steep liquor is drawn off by a plug at the bottom of the vat into another vessel, where it is beat and

stirred with bamboos for 1 to 3 hours, till the indigo granulates. When the grains are properly formed, cold water or lime water is added, and the liquor allowed to clear, and then drawn off. The indigo is placed in a copper boiler and gently boiled; it is then thrown on a filter, squeezed and dried.

Blue Indigo. — Blue rhombic needles, with a copper lustre, obtained by sublimation from common indigo by heating it between two platinum crucible covers; or it may be obtained as a powder from the indigo vat, by mixing, in a stoppered bottle, 5 indigo, 10 sulphate of iron, 15 slaked lime, and 60 water. After standing for some days the clear liquor is drawn off with a syphon; the indigo precipitates on the exposure of the liquor to the air; the indigo is to be washed with pure water and HCl, and lastly with alcohol. In this state it consists of C 73·28, H 3·82, N 10·69 O 12·21. *Form.* $C_{16} H_5 NO_2$. (*Crum, Dumas.*)

White Indigo, Indigogene, $C_{16} H_5 NO_2 + H$, is, according to the present view, blue indigo, with an additional atom of hydrogen. It exists in the indigo vat, and can be obtained by drawing off the vat liquor by means of a syphon filled with hydrogen, and mixing it with dilute HCl, to which sulphate of NH_3 has been added; a white precipitate falls of indigogene, which must be kept away from the air. It must be washed with boiling water, containing sulphate of NH_3; it dissolves in alkalies; in dry air it retains its colour; soluble in alcohol, but insoluble in water and acids. *Sulpho-indigotic acid, Saxon blue, Cerulin, Sulphindelic acid,* $C_{16} H_4 NO\ 2SO_3$. When 1 part of blue indigo is left in contact with 8 parts of oil of vitriol for some days, at a common temperature, or at 130°, a blue solution is produced, while a purple substance remains — *Sulphopurpuric acid,* $C_{32} H_{10} N_2 O_4\ 2SO_3$. The first acid is formed by the indigo losing an atom of water, while in the second acid the atom is doubled. *Oxidation and Chlorization of Indigo.* — When indigo is dissolved in diluted NO_5, colourless needles of *indigotic* or *anilic acid* separate by concentration: they consist of $C_{14} H_4 NO_9$. When the preceding acid is acted on further by NO_5, yellow prisms of *picric,* or *carbazotic acid,* or *bitter of Welter* ($C_{12} H_2 N_3 O_{13}$) are formed. When purified indigo blue is treated with a mixture of equal parts of SO_3, and bichromate of potash previously dissolved in 25 parts of water, the mixture gently heated until there is a slight disengagement of CO_2, and the liquid assumes a deep brown yellow colour; crystals make their appearance on cooling, which are reddish yellow rhombic prisms of *Isatin:* it is soluble in hot alcohol and water; the solution colours the skin. It consists of $C_{16} H_5 NO_4$, or simply indigo with 2 atoms oxygen derived from the chromic acid. When isatin is heated with caustic potash, a compound of *isatic acid* ($C_{16} H_6 NO_5$) with potash is formed. When isatin is dissolved in sulphohydret of ammonia, a white powder

isatyde, $C_{16}\ H_6\ NO_4$, separates on cooling. When, through a saturated alcoholic solution of isatine, SH is passed, *Sulphesatyde*, $C_{16}\ H_6\ NO_2\ S_2$ grayish yellow crystals fall, mixed with sulphur. One atom of sulphur can be removed from this compound by treating a solution of it in alcohol by KO. On adding the latter, drop by drop, the liquid becomes red, and white crystals fall of *sulphasatyde*, $C_{16}\ H_6\ NO_3\ S$. When sulphasatyde is rubbed in a mortar with strong caustic potash, the colour changes to red, and deepens by the addition of alcohol. The powder, when washed with alcohol, water, and dissolved in potash, yields a black solution, which deposits black crystals of *Indinate of potash*. When these crystals are washed with alcohol, H Cl and water, they become *Indine* $C_{16}\ H_6\ NO_2$. When sulphasatyde is treated with potash, yellow crystals of *Hydrindine* appear. Nitric acid converts Indine and Hydrindine into *Nitrindine* $C_{16}\ H_4\ NO_4\ O,\ NO_2$ — a violet powder. *Sulphisatanous* $C_{16}\ H_6\ N\ 2SO_2\ O_2\ NH_4O$ 2 Aq. is obtained by treating sulphesatyde with bisulphate of ammonia. *Isatane*, $C_{16}\ H_6\ NO_3$, is a white powder obtained in the preceding process.

If a current of chlorine be passed through a solution of isatin, an atom of hydrogen is replaced by Cl, and a new compound— *Chlorisatin*, $(C_{16}\ \underset{Cl}{NH_4}\ O_4)$ — is produced; a substance crystallizing in orange yellow 4-sided prisms, dissolving in 50 parts of boiling water and alcohol; it is converted into chlorisatic acid by caustic potash ($C_{16}\ H_5\ Cl\ NO_5$). By the further action of Cl, *Bichlorisatin* $(C_{16}\ N\ \underset{Cl_2}{H_3}\ O_4)$ is produced in red prisms, more soluble in alcohol and water than the preceding body. It forms an acid with potash. When chlorisatin is dissolved in hot sulphohydret of ammonia, *Chlorisatyde*, a yellowish white powder, separates on cooling ($C_{16}\ H_5\ N\ Cl\ O_4$). When chlorine is passed through an alcoholic solution of chlorisatin, pearly scales of *chloranil* ($C_{12}\ Cl_4\ O_4$) make their appearance, which are converted by potash into *chloranilic acid*. When chloranil is dissolved in hot NH_3 the solution becomes blood red, and crystals of *ammonia chloranil* ($C_{12}\ H_6\ Cl_2\ N_2\ O_6$) in the form of chesnut needles, appear. After the separation of this body, if HCl be added, *chloranilam* in needles separates. When chlorine is passed through water containing indigo blue in suspension, the whole becomes a yellow mass; when this is distilled, white needles, consisting of a mixture of *chlorindatmin* and *chlorindoptic acid*, condense in the neck of the retort, while chlorisatin and bichlorisatin remain in the retort. Bromine has a similar action to chlorine in all these cases of replacement.

Action of Alkalies on Indigo.—When indigo blue is boiled with caustic potash (sp. grav. 1·45) it dissolves into a yellowish fluid,

and, by evaporation, crystals of *chrysanilic acid* (C_{28} H_{11} N_2 O_6) and potash are obtained. When caustic potash (sp. grav. 1·35) is boiled with indigo blue, and finely powdered black oxide of manganese is added in small portions at a time, *anthranilate* (C_{14} H_6 NO_3) of potash is formed, which may be separated by crystallization. If indigo be decomposed by strong caustic potash or soda, and then distilled, *aniline*, a colourless oil, appears, (C_{12} H_7 N) with a sp. grav. 1·020, the boiling point at 360°, soluble in water and alcohol. It is obtained likewise among the oils of coal tar. When dry NH^3 is passed through a solution of isatine in alcohol, dark yellow crystals of *Imesatine* (C_{16} H_6 N_2 O_2) appear, in which oxygen is replaced by amidogen NH_2 or imidogen ($\frac{1}{2}$ NH) the rational formula being C_{16} H_5 N 2 Im. O_2. *Imasatine* C_{16} H_5 N Im. O_3 forms when caustic NH_3, is brought in contact with an alcoholic solution of isatine. *Amasatine*, C_{16} H_5 N Ad. O_3, a yellow body, obtained along with the preceding.

Litmus, *Lacmus*, *Turnsol*.— Blue cubical cakes, which come to this country from Holland, are so termed. It is prepared by reducing the lichen Lecanora tartarea to powder, mixing it with urine, and leaving them for thirty days in contact, when the blue colour gradually appears. Litmus consists of four substances; when it is boiled with water, and extracted with H Cl, a red matter remains, which is boiled with alcohol. This fluid takes up *erythrolein* and *erythrolitmin*, and some other bodies. Ether dissolves the two former, and drops the first as an oil on evaporating the ether (C_{26} H_{22} O_4); while the erythrolitmin (C_{26} H_{23} O_{18}) is obtained as a red powder, by the total evaporation of the ether. When the alcoholic extract, unacted on by ether, is mixed with NH_3, *azolitmin* is taken up. A red substance, termed *spaniolitmin* (C_{18} H_7 O_{16}), is sometimes, though rarely, present in litmus. (*Kane.*)

Litmus paper is prepared for testing by dipping letter paper into a filtered infusion of litmus, to which a small portion of carbonate of ammonia is added; or the paper may be previously dipped in a weak solution of that salt, and then into the litmus.

YELLOW COLOURING MATTERS. — The most important yellow colours are quercitron, which is extensively used in dyeing, obtained from the bark of the quercus tinctoria, *fustic* or *yellow wood* (morus tinctoria), weld or woad (reseda luteola), *anotto* (bixa orellana), much employed to dye cheese and to colour tooth powder; *turmeric*, the root of the curcuma longa, principally used for testing ammonia, and to mix with curry powder; *Persian berries* (rhamnus cathartica); *saffron*, from the crocus sativus; *parietin*, from the parmelia parietina.

Acids secreted by Plants.

The leaves, fruit, and stalks of vegetables often contain acids, united to a small amount of base, so as to render the taste acid. In the wood sorrel, the sour taste is due to oxalic acid; in apples, gooseberries, and rowan tree berries, to malic acid; in grapes, to tartaric acid; in oranges. and lemons, to citric acid. The theory of the process by which these acids are separated from the plants in which they exist, consists first in expressing the juice by strong pressure; second, in heating the juice, and adding to it a quantity of chalk or milk of lime (slaked lime made into a milk by the addition of water), and thus forming an insoluble lime salt; third, the lime is removed from the acid by means of sulphuric acid, the sulphate of lime filtered off, and the liquid containing the vegetable acid evaporated and crystallized.

Tartaric acid, $C_8 H_4 O_{10} 2HO$ 18·75, oblique rhombic prisms, obtained by dissolving crude tartar or argols, a salt which encrusts wine casks, in water, adding chalk or milk of lime; tartrate of lime is formed, which is decomposed by SO_3; from the sulphate of lime the solution of tartaric acid is decanted and crystallized; when heated in a flask with caustic soda, it is converted into acetate and oxalate of soda ($C_4 H_3 O_3$ and $C_4 O_6 HO$); when distilled with black oxide of manganese, formic acid, CO_2 and tartrate of MnO, is formed. Tartaric acid precipitates lime water, but not chloride of calcium, a distinguishing character from racemic acid: tartaric acid prevents iron from being precipitated by alkalies, and therefore appears to form a ferrotartaric acid. When tartaric acid is heated cautiously, it loses one fourth of its water, and becomes *tartralic acid* ($C_8 H_4 O_{10} 1\frac{1}{2} HO$), and by a further heat *tartrelic acid* ($C_8 H_4 O_{10} HO$); and at 302° it is rendered anhydrous and insoluble in water; when distilled, liquid pyrotartaric acid ($C_6 H_3 O_5 HO$), and solid paratartaric acid ($C_5 H_3 O_3 HO$) are obtained.

Bitartrate of Potash. Cream of tartar, $KO C_8 H_4 O_{10} HO$, oblique rhombic prisms, or irregular 6-sided prisms, very insoluble in water, is precipitated in wine casks in consequence of being insoluble in the alcohol of the wine. It is a useful test to distinguish potash from soda, in consequence of the insolubility of the potash salt. It is used in medicine as a mild aperient and diuretic; from it is made, by calcination, the purest form of carbonate of potash; when ignited in a clay crucible, it is converted into *black flux*. By digesting this in water, carbonate of potash is taken up. (For double tartrates see *Antimony*.) A neutral tartrate is obtained by adding carbonate to cream of tartar solution till effervescence ceases.

Potash Tartrate of Soda — Rochelle Salt — 6 to 10-sided right rhombic prisms; a pleasant aperient, formed by adding carbonate of soda to a solution of cream of tartar. This salt enters into the composition of some of the effervescing salts. (See Soda for Effervescing Draughts.)

Racemic acid, paratartaric acid, $C_8 H_4 O_{10}$ 2HO, oblique prisms, with a rhombic base; a remarkable acid, isomeric with tartaric acid, but forming distinct salts. It precipitates lime water and chloride of calcium, and is therefore a stronger acid than tartaric acid. Heat converts it into paratartralic, paratartrelic acid, and hydrous racemic acid, similar to the products of tartaric acid. Racemic emetic crystallizes in 4-sided prisms with a rhombic base.

Malic acid, $C_8 H_4 O_8$ 2HO, in grains, may be obtained from apples, rhubarb, or rowan tree berries, by expressing the juice, heating it to separate albumen, then adding milk of lime. On boiling, the dimalate of lime falls. This salt is dissolved in dilute hot nitric acid; on cooling, the neutral malate of lime crystallizes, from which the acid may be separated by SO_3. When malic acid is distilled rapidly, *maleic acid* ($C_8 H_2 O_6$ 2HO), in oblique prisms, with a rhombic base, appears in the receiver, differing from malic acid by containing two atoms of water less. When malic acid is retained at a temperature a few degrees above its fusing point, it is converted into *paramaleic* or *fumaric* acid ($C_4 H O_3$ HO). It appears in soft mica like scales.

Citric acid (Scheele, 1784) $C_{12} H_5 O_{11}$ 3HO, rhomboidal prisms, terminated by four faces; obtained by neutralizing lime juice with chalk, and decomposing the citrate of lime (3CaO $C_{12} H_5 O_{11}$ 4HO) by SO_3. It precipitates hot lime water; it unites with three atoms of base, forming salts with lead, barytes, silver, &c., and an emetic with splendent crystals. When citric acid is distilled it first loses its crystalline water: it is then converted into *pyrocitric* or *aconitic* acid ($C_4 H O_3$ HO); also found in monkshood, a crystalline mass: by further heat it is changed into *pyroaconitic acid* (*Citricic* or *Itaconic*) $C_5 H_2 O_3$ HO), in octahedrons. When the latter acid is heated, it yields *pyroitaconic* or *citraconic acid* (citribic acid), $C_5 H_2 O_3$ HO, a volatile oily liquid.

Tannic acid, Tannin, $C_{18} H_5 O_9$ 3HO. — Yellow mass occurs in oak bark and in many trees; and may be separated from nut-galls by reducing them to a coarse powder in a mortar, and covering them in a percolator with a mixture of ether and water. The fluid passes through the powder into a bottle beneath, in which two strata of fluid separate; the lighter consists of gallic acid dissolved in ether; the lower of tannic acid in water. On evaporation tannic acid separates. It precipitates a solution of glue — forming *leather*. When a piece of skin is placed in a

solution of tannic acid, the latter is entirely removed from the solution. *Tannate of peroxide of Iron, or Ink*, 3 (C_{18} H_8 O_9 3HO) F_2 O_3 is prepared by adding the acid to a persalt of iron. A good *black ink* is made by boiling bruised nut-galls 2¼ imperial lbs. in 28 lbs. water, filtering and dissolving in it in an open vessel, 1 lb. sulphate of iron (green vitriol), and 1 lb. of gum arabic. When it is dark blue it may be carefully bottled up. Tannic acid, by absorbing oxygen, is converted into *gallic acid*, C_7 HO_3 3HO, pale yellow brilliant prisms. It is separated from nut-galls by ether as previously described. It forms blue precipitates with iron. When tannic and gallic acids are distilled, *pyrogallic acid* (C_2 HO), in star-like needles, appears in the receiver, while the *metagallic acid* (C_6 H_2 O_2) remains as a black powder. When infusion of nut-galls is exposed to the air, gallic acid appears, and an insoluble gray powder, but soluble in alkalies, and precipitated by acids, *ellagic acid* (C_7 H_3 O_5). This acid is found in some concretions or bezoar stones from the intestines of eastern animals. *Catechu*, an extract from a mimosa, is soluble in cold water: *Catechine* (C_{15} H_6 O_6) is the insoluble part of catechu in cold water, but is soluble in hot water and alcohol; it crystallizes in silky needles. It forms a green compound with peroxide of iron, and does not precipitate glue. By oxidation *japonic* and *rubinic* acids are formed.

Meconic acid, C_{14} HO_{11}, pearly scales, obtained by adding to 1 part of meconate of potash dissolved in 18 of hot water, 3 parts of HCl; acid meconate of potash precipitates; by repeating the process pure meconic acid is obtained. Meconate of lime, the refuse of the morphin manufactory, may be treated in the same way. Precipitates persalts of iron blood red, thus affording a very delicate test. The meconates consist of 1 acid and 3 of base. The most important are the meconate of lime, and the meconate of potash, made from the first, by treatment first with HCl, and then with potash. When meconic acid is boiled with water and HCl, it is resolved into *comenic acid* C_{12} H_2 O_8 2HO, in hard crystalline grains precipitating iron red. When comenic acid is distilled, it yields at 570° *pyromeconic acid*, C_{10} H_3 O_5 HO in crystals precipitating iron red.

Kinic acid (Hoffman, 1790), C_7 H_4 O_4 2HO in crystals, obtained by treating kinate of lime, the refuse of the quinine manufacture by oxalic acid or by SO_3. It appears to unite with 2 atoms of base. When distilled with dilute SO_3, MnO_2 *Kinone*, (C_{25} H_8 O_8), appears in golden crystals. If SO_2 be added to kinine, *green hydro-kinone* is produced (C_{25} H_{10} O_8) in gold green crystals. If an excess of SO_2 be employed, *white hydro-kinone* (C_{25} H_{12} O_8) appears in 6-sided prisms. A variety of compounds may be formed from these by substitution. *Chelidonic acid*, C_{14} H_2 O_{10}, white needles, from chelidoninm majus.

Oils, Fats, and Oily Acids, mostly secreted by Plants.

In the cells and fluids of certain plants, and also of animals, we find peculiar bodies deposited, familiarly known under the names of oils, fats, and butters, extracted by pressure or by heat. Oils are extracted by pressure and by heat from the seeds in which they are contained. Oils are usually divided into four classes. 1. *Drying oils*, including oils of linseed, walnut, hemp, poppy, castor, croton, grape seed, nightshade, tobacco, henbane, sunflower, cress. These are distinguished by their *drying up* in the air, or becoming solid, but remaining transparent. To this class belong the oils employed for making printers' ink; nut oil being the best. 2. *Fat oils.* These dry up in the air by absorbing oxygen, but they become opaque and fatty, including oils of olives, almonds, rape, mustard, plums, beech, hazel, ants' eggs, train or whale, spermaceti, seal, herrings, cod's liver. 3. Butters and solid oils at the usual temperature, cacao, palm, nutmegs, laurel, cocoa nuts, Shea butter, Minia batta, Chinese-tree tallow, hog's-lard, cow's butter. Allied to these are the waxes — bees' wax, Japan wax, myrtle wax, cork wax, cholesterine (bile and brain wax), ear wax, ambergris, castorine, spermaceti, sugar-cane wax. If we take mutton fat, and expose it to pressure between leaves of blotting paper, an oily stain is left on the paper. If the paper be now immersed in boiling water, the stain disappears, and a fluid oil is observed to float on the surface of the water. This substance is termed *Oleine* or *Oleate* of the oxide of Glyceryle (GlyO Ol). There remains unacted on by the paper a white solid substance, termed *Stearine* or stearate of the oxide of Glyceryle (GlyO St_2). The cause then of the solid nature of mutton fat is the predominance of the solid stearine in it, while it contains only a small portion of the liquid oily body, oleine. Hence the difference between a liquid and a solid oil or butter depends upon the presence in the liquid oil of a large quantity of the liquid oleine, and a minute quantity of stearine, while in a solid oil the stearine is most abundant. To prove that a liquid oil contains a solid substance in solution, we have only to expose it to the action of snow or ice; when the stearine is deposited, and the olein floats above. Thus it is, that in winter olive and castor oils become thick, and deposit a white solid matter. As the olein and stearine consist each of an acid united to a base — the oxide of glyceryle, they may be considered as oily salts; — and on this view the process by which they are converted into *soaps* becomes easy of appreciation. The change produced on mutton fat depends on the replacing the oxide of glyceryle, by an alkaline base, potash, and thus converting the solid oily stearate of oxide of glyceryle, insoluble in water, into a stearate of oxide

of potassium, — a *soap* which is quite soluble in water, GlyO St_2 and KO becoming KO St_2 and GlyO set free. *Saponification*, or the formation of soap, is effected by boiling oils with a solution of caustic potash or soda. The experiment may be made, on a small scale, in an iron or silver bason. The boiling is kept up, using an excess of alkali, until the whole of the stearic or other oily acid has been separated from the oxide of glyceryle, and has united with the potash. The matter contained in the bason should therefore dissolve completely in hot water if the soap is thoroughly formed. From this solution the soap may be precipitated by adding a strong solution of common salt, to remove from it glyceryle, and may be again dissolved in water — from which solution the fatty acid may be separated by the addition of HCl or tartaric acid, which will unite with the potash, and set the acid free. Soaps thus made with soda, being firm, are called *hard* soaps: those made with potash, being soft and deliquescent, are termed *soft* soaps. Instead of the alkalies, the fat acids may be united with metallic oxides, and *plasters* or metallic soaps formed. Litharge or *diachylon* plaster, which forms the basis of medical plasters, is produced by boiling 1 part of litharge (Pb O), with 2 of olive oil.

Stearic acid, C_{68} H_{66} O_5 2HO, pearly scales, melts at 167°, spec. grav. then 0·854; in solid state 1·, formed by boiling mutton or ox fat with caustic potash, and liberating the fat acid by HCl. The oleic acid is then separated from the stearic acid by pressure between hot plates. The solid stearic acid resembling wax is repeatedly dissolved and crystallized from alcohol, until its melting point is steadily 167°. Stearic acid constitutes the principal portion of what are called stearine candles. The acid is first united with lime to form a lime soap, — which is decomposed by HCl, and the stearic acid liberated. With potash and soda, it forms two soaps, one with an excess of acid. Common *white soap* is made by boiling 13 cwt. of tallow with 4 of soda ash, deprived of all its carbonic acid by means of lime. Yellow soap is formed of $9\frac{3}{4}$ cwt. tallow and palm oil, $3\frac{1}{4}$ rosin, and 4 soda ash. Soaps, when dissolved in water or alcohol, are delicate tests for earthy matter in waters with which they form flocky precipitates.

Margaric acid, C_{68} H_{66} O_6 2 HO, pearly scales; melting point 140°. It exists in human fat, butter, goose fat, olive oil, &c. united with Gly O; it may be formed from stearic acid, by heating it with an equal weight of NO_5 for a few minutes; pressing to remove oleic acid, and crystallizing out of alcohol repeatedly. When stearic acid is distilled, margaric acid passes over, mixed with margarone, from which it is separated by dissolving the mixed fats in potash, and precipitating by Ca Cl. Margarone is dissolved up from this precipitate by ether, while margarate of

lime remains, which is decomposed by H Cl. *Margarone* C_{66} H_{66} O_2, or margaric acid, less two atoms CO_2, a crystalline fat, fusing at 190° to 200°. It appears then that by distillation stearic acid gains an atom of oxygen to be converted into margaric acid. *Margarate of Glyceryle, Margarine*, is found abundantly in human and goose fat, and in olive oil when cooled: it has never been quite purified. The potash and soda soaps are similar to those of stearic acid. *Oxidation:* stearic and margaric acids, by the continued action of NO_5, are converted into *suberic acid*, C_8 H_6 O_3, white crystalline powder, with acid taste, melting when moist at 130°, when dry at 238°: above this it sublimes in long needles; soluble in hot water, alcohol, and ether; and in cold ether, which enables us to separate it from succinic acid. It is monobasic, sublimes above 240° into an oily liquid, becoming needles. By dissolving margaric acid by long boiling in NO_5, evaporating to one half, it deposits crystals of suberic acid, which are washed with cold water and recrystallized. This acid is formed also by the action of NO_5 upon cork. Besides suberic acid, another acid is obtained by oxidizing margaric acid, *succinic acid*, C_4 H_2 O_3 HO, colourless scales or prisms, with acid taste. Specific gravity 1·55; volatile, giving a buff precipitate, with salts of peroxide of iron. With ammonia, and the ethyle salt, *succinamide*, a solid is formed. This acid is a product of the oxidation of stearic and margaric acids, and of wax, spermaceti, and asparagine. This acid exists ready formed in amber, a fossil resin, from which it may be separated by distillation, filtration, crystallizing, and subliming. *Sulphuric acid* converts margaric acid into *metamargaric, hydromargaritic*, and *hydromargaric* acids, all solid and crystalline.

Oleic acid, C_{36} H_{33} O_3, clear fluid oil, above 57°, congeals at 20°, in white needles, without taste or smell, and acid reaction; above 60° it is easily oxidized; insoluble in water, soluble in alcohol and ether: procured from almond oil by forming a soap with potash; separating the acid, uniting it with oxide of lead, dissolving the lead salt in ether, and decomposing by dilute H Cl. It is further purified by frequently uniting it with soda, and throwing it down by common salt, and lastly, by congealing it, and pressing in paper, until it permanently fuses at 57°; when solid it is in snow-white needles. Its soaps contain 1 atom of base. Oleine has never been obtained pure. *Heat* converts oleic acid into *sebacic acid*, C_{10} H_8 O_3 HO, pearly scales, like benzoic acid, melting at 260° to an oil soluble in hot water, alcohol, and ether, and uniting with bases to form salts. The presence of sebacic acid is a characteristic test of the previous presence of oleic acid, or an analogous acid, but not of a solid acid. It is little soluble in cold water, very soluble in hot water, alcohol, and ether. To detect oleic acid, distil the oil supposed to contain it; boil

the distilled matter with water. If crystals are deposited when the solution cools, and if the liquid when hot precipitates salts of lead, it is a proof that sebacic acid is present, and that oleic acid has existence in the distilled oil. Capric, caprylic and traces of valerianic and butyric acids, pass also into the receiver. *Nitric acid*, when boiled in a retort with oleic acid, gradually dissolves the acid, and forms suberic acid, which deposits in crystals when the mixture is evaporated to one half. After depositing this acid, the liquid is further evaporated, and deposits hard grains of *pimelic acid*, $C_7 H_5 O_3$, fusing point 273°, and subliming in scales. By further evaporation, *Adipic acid*, $C_6 H_4 O_3$, radiated brownish masses, melting at 266° deposit, and *Lipic acid*, $C_5 H_3 O_4$, long plates fusing at 290°. On the surface of the NO_5 floats an oil which is changed into *azoleate* ($C_{13} H_{13} O_4$) of ethyle, by boiling with alcohol and SO_3. The volatile acids produced in this process of oxidation are the acids found in butter, acetic acid, metacetonic acid, valerianic acid, œnanthylic acid, and pelargonic acid. *Nitrous acid* evolved from starch and NO_5, converts oleic acid into *Elaidic* acid, in pearly scales fusing at 113°, soluble in alcohol. It is also formed by nitrate of mercury in contact with oleic acid, as in citrine ointment. It is isomeric with oleic acid, and is altogether a remarkable substance, as it can only be formed by NO_3, and yet contains none of that acid. *Sulphuric acid* converts oleic acid into *metoleic acid*, $C_{70} H_{63} O_8 HO$, a liquid soluble in ether, and insoluble in water; and *hydroleic acid*, a liquid insoluble in HO, very soluble in alcohol and ether; containing an atom of water more than the preceding acid. *Palmic acid*, $C_{34} H_{32} O_5 HO$, in crystals, is obtained by heating castor oil with nitrous acid, and saponifying the product. *Œnanthilic acid* is obtained by heating castor oil with NO_5.

Acids of Butter. —When butter is saponified by potash, and the soap is decomposed by tartaric acid, margaric acid rises to the surface as a fatty substance, while the volatile acids, butyric, caproic, caprylic, capric, vaccinic, remain in solution in the water. The fatty matter is removed, and the volatile acids being distilled over, they are neutralized by caustic barytes, and evaporated to a dry mass. This mass is boiled with six parts of water, when butyrate and caproate of barytes are taken up, and caprylate and caprate of barytes remain. The butyrate dissolves in 2½ parts of water, the caproate in 12½; so that by using a small quantity of water—2¾ to 1 of salt—the butyrate is dissolved with only a trace of caproate. Again, the caprylate is more soluble in water than the caprate, which requires 200 of water. *Butyric acid* $C_8 H_7 O_3$, clear oil; taste acid; smell like rancid butter, specific gravity ·963; boiling point 327°; burns with a smoky flame. It may be prepared as above, by decomposing butyrate of barytes by HCl, and distillation, or from sugar, as in the pre-

paration of lactic acid, already described. Lactate of lime is first formed, but it gradually dissolves, and is converted into butyrate of lime, which is distilled with a small excess of HCl. The fluid in the receiver is butyric acid in water. It is distilled over CaCl, to remove the water, and the process repeated until the acid boils at 327°. *Butyrate* of ethyle is an ethereal fluid, used to flavour rum. *Butyrone* is formed by distilling butyrate of lime, from which CO_2 is removed. *Butyramide* is formed when NH_3 acts on butyric ether. Butyric acid occurs among the products of the oxidation of albuminous substances, and also in their putrefaction. *Caproic acid*, $C_{12}H_{11}O_2HO$, clear oil; boiling point 396°; smell resembling sweat; occurs in small quantity in butter. *Caprylic acid*, $C_{16}H_{15}O_3HO$, volatile clear oil; boiling point 465°. *Capric acid*, $C_{20}H_{19}O_3HO$, a clear liquid, boiling at 534°, with the smell of the goat, and on decomposing, the odour of Roquefort cheese. *Vaccinic acid*, $C_{20}H_{19}O_5$, a rare acid, resembling the preceding; but it is probable that it exists in butter, and is converted into caproic and butyric acids in the process. These acids differ in containing different proportions of CH, the addition of every 2 atoms of which raises the boiling point 34½°. *Pelargonic acid*, $C_{18}H_{17}O_3HO$, is intermediate between caprylic and capric acids, but is little known. It also appears in the oxidation of oleic acid.

Palmitic acid, $C_{32}H_{31}O_3HO$, pearly scales, like margaric acid; fusing point 140°, obtained by saponifying palm oil with potash; it is partially decomposed by distillation. *Palmitate of glyceryl*, the essential part of palm oil, is a crystalline white solid, soluble in hot ether. *Oenanthic acid*, $C_{14}H_{13}O_3$, an oily liquid above 60°, without taste and smell; at 54° it is solid, insoluble in water, soluble in alcohol and ether: occurs in wine and whiskey, and when old wine is distilled, comes over strongly at the end of the process, as oenanthate of ethyle, giving the disagreeable smell to old wine casks.

Lauric acid, $C_{24}H_{23}O_3HO$, crystalline, fusing at 112°, soluble in alcohol and ether, obtained by saponifying the fat of laurel berries.

Crotonic acid, volatile, solid, nauseous taste, poisonous: from croton oil.

Sabadillic acid, white needles, with smell of butyric acid, fusing at 70°, by forming a barytes salt with the oil of veratrum sabadilla, and heating with PO_5.

Veratric acid, $C_{18}H_9O_7$, white prisms, soluble in water and alcohol, and insoluble in ether; obtained by treating the seeds of veratrum sabadilla with a mixture of alcohol and SO_3, precipitating the solution by milk of lime, and decomposing the lime salt by HCl.

Camphoric acid, $C_{10}H_7O_3HO$, small scales or needles, obtained by treating camphor with NO_5 until it is dissolved; the acid remains insoluble, and is combined with potash and crystallized, and decomposed by NO_5. Camphor $C_{10}H_8O$. is analogous in composition to resins. It is obtained from the *Laurus* Camphora. *Cocostearic, Cocinic acid* $C_{44}H_{44}O_4$ needles, fusing at 94½° from cocoa nut oil. *Anamirtic acid* $C_{70}H_{68}O_3HO$ needles from anamirta cocculus. *Roccellic acid*, $C_{17}H_{16}O_4$, white needles, fusing at 295°; obtained from archil. (roccella tinctoria), by treating the lichen with NH_3, and precipitating with CaCl. The lime salt, being decomposed by weak HCl, yields the acid which is purified by ether.

Cetylic or *Ethalic acid*, $C_{32}H_{32}O_4$, fatty, and melting at 130°. Volatile, insoluble in water, soluble in alcohol and ether. It has the same composition as palmitic acid, but different properties; prepared by heating 1 part of ethal

(already described), with 6 parts of fused potash and quicklime to 425°. Hydrogen is liberated, and cetylate of potash formed; the salt is decomposed by barytes, by treating it with Ba Cl; the ethal is removed by ether, and the barytes salt decomposed by HCl. *Myristic acid*, $C_{28} H_{27} O_3 HO$, fine white scales, fusing at 120°, soluble in alcohol and ether; occurs in butter of nutmegs united with GlyO; the butter is heated with hot alcohol, and the silky crystals deposited are saponified. *Oenanthylic acid*, $C_{14} H_{13} O_3 HO$, produced by the action of NO_5, on castor oil, and on oleic acid. *Oenanthole*, $C_{14} H_{13} O HO$, a fluid obtained by distilling castor oil, boiling at 312°. *Cuminic acid*, $C_{20} H_{11} O_3 HO$, white crystals, formed by dropping oil of cumin or caraway into fused potash.

Caryophyllic acid, *Eugenic acid*, $C_{20} H_{12} O_4$, colourless oil: 1·079 specific gravity: formed by saponifying the oil of cloves with potash, and distilling with SO_3; boils at 243°, with an acid reaction.

Wax. — There is some reason for considering wax to be a deoxidized fat. When bees' wax is boiled with alcohol, *cerotic acid* $C_{54} H_{54} O_4$ is taken up. It is crystalline and volatile without change, melting at 79½°. By chlorine it is converted into a gum resin $C_{54} H_{42} Cl_{12} O_4$. It does not occur in Ceylon bees' wax. It exists, however, in wax from China, in the form of an alcohol *cerotine* $C_{54} H_{56} O_2$, melting at 79°. — (*Brodie*). The portion of wax not dissolved by alcohol is termed *Myricine*, but has not been carefully examined. Other species of wax are in course of examination by Mr. Brodie.

Essential Oils destitute of Oxygen.—These oils are obtained by distillation from balsams, and from the fruits of some plants. They have all the same formula, or $C_{10} H_8$. *Oil of Turpentine.* Colourless fluid, spec. grav. ·87; neutral; boiling point 312°; spec. grav. of vapour 4·764, insoluble in water, soluble in alcohol, ether, and fixed oils. It is obtained by distilling turpentine, a semi-fluid mass, from pines, &c.; takes fire when equal parts of SO_3 and NO_5 are poured into it; Cl replaces a portion of the hydrogen; NO_5 converts it into *terebinic acid.* Oils of lemons, juniper, sabine, storax, elemi, oranges, orange-flower, copaiba, cubebs, and pepper, are examples of the same class of oils. *Oils containing Oxygen.*—The type of these oils may be illustrated by oil of cinnamon, a pale yellow fluid; spec. grav. 1·06; aromatic smell, and sweetish taste, $C_{18} H_7 O_3$. When exposed to the air it is converted into a resin $C_{30} H_{15} O_4$ by the absorption of oxygen. These oils contain often a solid fat, *stearoptene*, which is deposited by cold. The stearoptene of the Tonka bean is called *Coumarin*, is aromatic, and is the cause of the odour of Woodruff, and of the sweet grass, Anthoxanthum odoratum. *Anise Oil* yields, with fuming SO_3 anisyle. What are usually termed *essences* belong to this class. In certain oils we find sulphur, as in oil of mustard, or *Sulphocyanide of Allyle*, $C_6 H_5 C_2 NS_2$. Its compound with ammonia is a base *Thiosinnamine*, from which by PbO *Sinnamine* $C_8 H_6 N_2$ is obtained.

V. Excretions of Plants.

Resins are oxides of essential oils, in which the oxygen has replaced an equal amount of hydrogen, being derived from the formula $C_{10} H_8 \times 4 = C_{40} H_{32}$. The simplest resin consists of $C_{40} H_{31}$. Common rosin, obtained by distilling off oil of turpen-

tine from turpentine balsam, has the formula C_{40} H_{32} O_4. Resins are divided into acid and neutral. 1. *Acid resins*, when dissolved in alcohol, redden litmus; and, if ammonia is added, they precipitate nitrate of silver with a crystalline precipitate, not redissolved by an excess of ammonia. The neutral resins are not affected in this way. Acid resins decompose carbonate of soda; they dissolve in caustic soda, and potash. Their solution in spirit is not precipitated by NH_3; the precipitate produced sometimes by water is soluble in NH_3; their soaps are not precipitated by common salt. The acid resins are common rosin or Colophony, Dammara, Gamboge, Sandarach, Mastic Benzoin, Copal, Lac, &c. When the resins are distilled they give oils of various constitution, which sometimes contain creasote, and are used to preserve timber. At higher temperatures they yield gases for lighting. 2. *Neutral resins* have their alcoholic solutions precipitated by ammonia: they do not redden litmus. To this class belong Elemi, Styracine, Guiacum, Dragon's blood.

Gum Resins are more opaque than resins. They do not melt like resins when heated, have a strong odour, partially soluble in water, and in alcohol more particularly, when dilute; soluble in caustic alkalies. They may be divided, according to their action on animals, into five classes. 1. *Fetid.*—Consisting of ammoniac, galbanum, asafœtida, opoponax, sagapenum. 2. *Stimulating.*—Olibanum, used as frankincense; myrrh, used in hysteria; euphorbium, and bdellium. 3. *Cathartic.*—Aloes, entering into the composition of aperient pills. From it, by oxidation, are obtained three acids: *Polychromic acid*, a yellow or brown powder, obtained by treating 1 aloes with 9 NO_5, and evaporating to a syrup; by washing with water it is purified. *Chrysammic acid* C_{15} HN_2 O_{12} HO, golden scales; by distilling 1 aloes with 8 NO_5, spec. grav. 1·37, and keeping at the boiling point for some days, and adding water, this acid is precipitated and purified with potash and NO_5. Its salts are red. *Chrysolepic acid.*—C_{13} H_2 N_3 O_{13} HO, golden scales, isomeric with picric acid and possibly the same is dissolved by the water, when chrysammic acid is precipitated. The solution is evaporated, and the acid purified by potash. *Styphnic acid*, obtained by the action of NO_5 on gum ammoniac. The other cathartic gum resins are gamboge, a yellow colouring matter, and scammony. 4. *Sedative gum resins.*—Opium obtained from species of poppies: lactucarium from lactuca sativa; upas, consisting of igasurate of strychnin, from the strychnos tieute, the poison tree of Java. Allied to the resins are *caoutchouc* or *Indian rubber*, and *Gutta percha*, both important bodies in the arts; the former is derived from various species of *ficus*, and the latter from *Isonandra gutta*, a tree of Malacca. They are obviously oils excreted by plants, and oxidizing in contact with air.

CHAPTER VII.

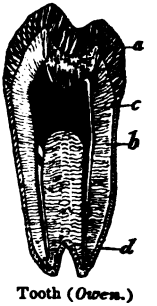
ANIMAL CHEMISTRY.

THE appearance which an animal or plant presents in the first stage of its existence is exactly the same, — that of a cell, or space surrounded by walls. In the plant, CO_2 and HO are absorbed into these cells, and are converted into solid matter; but in the animal, there is no such power existing. The animal increases in size, and prevents its substance from wasting by appropriating to itself its ready-formed food in plants, or in other living beings of its own nature. The cellulin which constitutes the sides of the cells in plants, consists of carbon, hydrogen, and oxygen, and yields by distillation acetic acid; while the cellular matter of animals contains, in addition to these three gases, a fourth, nitrogen, and yields to heat ammonia. A plant may therefore be defined to be an organized being, which derives its food from gases and from the soil; while an animal subsists by incorporating into itself, from foreign sources, matter similar to that of which its own substance is composed. The food therefore of animals being stored up in plants for their use, it is obvious that animals are originally derived from plants, and hence the dependence of the one class of beings on the other. The main constituents of the food have already been described in treating of the composition of flour. It remains now to trace the changes which such substances undergo in their passage through the animal system. These may be divided into various stages: — 1. Mastication or chewing, and Deglutition or swallowing; 2. Primary digestion in the stomach and intestines, or solution and preparation for absorption by the lacteals to be conveyed into the blood; 3. Secondary digestion, or sanguification, or conversion into blood; 4. Deposition of solid matter from the blood, or nutrition; 5. Removal of substances from the blood, or secretion and excretion; and, 6. Exhalation, including the action of the skin and lungs, or respiration.

1. *Mastication.* — The organs of mastication are situated in the mouth, and consist of the teeth, tongue, and cheeks. The teeth

consist of 3 parts: the *enamel* (*a*), which covers the crown of the tooth, is formed of fibres or tubes, laid parallel to each other, fig. 99.; the *ivory* or *dentine* (*b*) constitutes the body of the tooth, while the *crusta petrosa*, or *cement* (*d*), is laid exteriorly over the fangs. The specific gravity of human enamel is 2·711; of ivory, 2·105; of elephant's ditto, 1·728; of decayed teeth, 1·533; of a human humerus, 1·75; of a whale rib, 2·102; of Walrus ivory, 1·909. The composition of these structures in man is represented in the following table, along with that of decayed teeth, and of bone dried at 212°.

99.



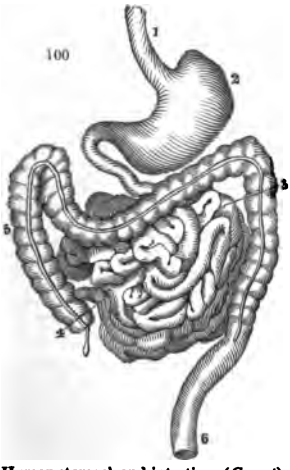
Tooth (*Owen.*)

	Enamel.	Ivory.	Carious Tooth.	Bone.	Tartar.
Animal matter 2.		25·38	57·78	33·30	20·59
Phosphate of lime Fluoride of calcium	88·5	54·14	30·00	53·04	73·30
Carbonate of lime	8·0	5·76	2·09	11·30	0·28
Phosphate of Magnesia	1·5	1·37	2·05	1·16	3·93
Water		10·37	9·45		
Alkaline chlorides		3·02	1·25	1·20	0·14

The structure of the teeth affords some insight into the mode in which they decay, for when the enamel is worn off, the ivory is exposed in the form of tubes filled with calcareous matter. The acid of the unhealthy mucous membrane and saliva dissolves out the carbonate of lime, and renders the tubes empty, and allows foreign matter to enter. The teeth thus lose their earthy matter, and become gradually dissolved down to the pulp and nerve (*c*), when toothache occurs. The enamel contains very little animal matter, and is usually removed principally by friction, when the ivory disappears by decay or solution, as described. The teeth are not supplied with nerves or blood vessels, and are therefore incapable of restoring lost portions. In an adult they are 32 in number, consisting in each jaw of 4 incisors, cutting or front teeth; 2 canine, dog or eye teeth; 4 bicuspid, smaller grinders or molars, and 6 grinding teeth, larger grinders or molars. In order that the food may be reduced to a properly formed pulp by the teeth, it is necessary that it should be mixed with a proper proportion of fluid. This is supplied by the parotid gland before the ear (when swelling causing the mumps), and by the glands under the tongue and jaws, which pour out the *saliva* or spittle to the extent of 1¾ lbs. per day. This fluid contains in 100 parts 98·88 water, animal matter 0·63, chloride of calcium 0·18, potash and soda, with some animal matter, ·292, phosphate of lime ·017, silica ·015. When the pulp has been

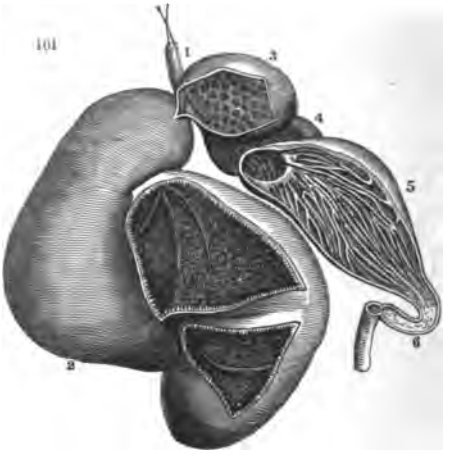
properly formed, it is carried to the back part of the tongue, by which organ it is projected into the throat; when the morsel is grasped by the muscles and conveyed involuntarily by the gullet, and without sensation, into the stomach. This process is usually termed *deglutition* or *swallowing*.

2. *Primary digestion* takes place throughout the whole of the intestinal canal, which extends from the mouth to the lower extremity of that tube — including, therefore, the stomach and bowels. When the masticated food arrives in the stomach, in the course of an hour or two it becomes acid, from the extrication of lactic and acetic acids. If starch has formed a part of the food, we find on filtration that the liquid does not render iodine solution blue, but purple, — a proof that the starch has become dextrin or soluble starch; and in the solution there exists much sugar, although none may have been swallowed. The fibrin, casein, and albumen are all dissolved apparently by the assistance of matter derived from the secreting coats of the stomach; while fat is not dissolved, but passes directly into the blood. The lactic acid ($C_6H_5O_5$) is formed at the expense of the sugar (produced again from the starch), by the division of the atom of that proximate principle. The cause of the solution of the nitrogenous principles appears to depend upon the action of a substance, probably modified albumen, which is contained in the secretion from the coats of the stomach. The true explanation of this solution is, however, yet to be sought for. In the stomach (fig. 101.), the food assumes a more pulpy appearance than when recently chewed. A portion of it passes by the lower extremity of the stomach into the small intestines, but much of it appears to be carried away through the coats of that organ, probably into the veins. That portion which passes into the *duodenum* and small intestines (6) is white, and called chyle. It is taken up by the lacteals, or small vessels, which convey it into glands, and



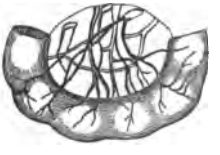
Human stomach and intestines (*Grant*).
1. Gullet; 2. Stomach; 3. Small intestines; 4. Termination of small in large intestines; 5. Colon or curved gut; 6. Rectum or straight gut.

ultimately into the thoracic duct, a tube passing upwards along the spine towards the heart. *The Bile.*—A little below the infe-



STOMACHS OF COW (*Carus* and *Jones.*)—(1.) *Gullet* by which the food passes into (2) the *paunch* or first stomach, whence the food passes into (3) the second stomach, or *honey-comb*. From this stomach it passes into the mouth, and is again masticated (chewing the cud). It is then swallowed, and goes to (4) the third stomach, or *manyplies*, and then into (5) the fourth stomach, or *red*, the true digesting stomach. Lastly, it enters (6) the small intestines.

rior or pyloric orifice of the stomach, the pancreatic or sweetbread fluid, a substance analogous to the saliva, and the *bile* from the gall bladder of the liver, are poured into the intestine. The *bile*



Lacteals which absorb the digested food from the intestinal canal, and carry it to the thoracic duct.

is a yellow fluid, becoming greenish by exposure to the air, with a sweetish bitter taste. *Test.* — Bile may be detected in solu-

tions, by adding to the liquid containing it its bulk of SO_3, and then a few drops of a weak solution of sugar. A fine pink colour is produced. When evaporated at 212°, a greenish yellow residue remains, from which alcohol takes up the greater portion, leaving a green colouring matter and some mucus undissolved. The true bile is dissolved by the alcohol, and may be deprived of colour by animal charcoal. It is then a compound of bilic or choleic acid and soda, and may be crystallized by dissolving it in 20 parts of absolute alcohol, and then adding ether till the solution becomes slightly milky; on standing, needle-shaped crystals are formed, consisting of $NaO\ C_{44}\ H_{40}\ NSO_9$. Bilic acid may be separated by precipitating by acetate of lead, and throwing down the lead by SH. The following table gives the composition of the substances obtained from bilic or choleic acid.

	Bile.	Bilic Acid.	Choloidic Acid.	Taurin.	Cholic Acid.	Cholesterin.
Carbon	58·33	63·70	73·30	19·24	68·50	85·09
Hydrogen	8·30	8·90	9·70	5·78	9·70	11·88
Nitrogen	3·70	3·90		11·29		
Sulphur }	22·64	4·00		38·40		
Oxygen }		19·50	27·00	25·29	21·80	3·03
Soda	6·53					
Common salt	0·37					

Bilic acid is colourless or yellow, like gum, of a resinous consistence, and is very bitter, dissolving in water and alcohol, but not in ether. When boiled with HCl, a resin falls down, which is *choloidic acid* ($C_{60}\ H_{50}\ O_{11}$) a yellow resinous body, insoluble in water, soluble in alcohol, uniting with bases. In the solution we find common salt, sal ammoniac, and *taurin* ($C_4\ H_7\ NS_2\ O_6$), fine crystalline needles, soluble in water, insoluble in alcohol, by the addition of a large quantity of which fluid it crystallizes out of the liquid. When choloidic acid is boiled with NO_5 in a retort, a violent action occurs, and much foam is produced. There distil over a heavy and light oil. The upper layer consists of capric, caprylic, valerianic, butyric, and acetic acids, principally the acids of butter, while the heavy oil contains nitrocholic acid (corresponding with $2NO_5$ and 1 urea), forming a salt with potash and *cholacrol* ($C_8\ H_5\ N_2\ O_{13}$), both of which substances have a powerful odour. In the retort remain *choloidanic acid* in hairy tufts, ($C_{16}\ H_{12}\ O_7$) and *cholesteric acid*, a gummy substance ($C_8\ H_4\ O_4$), forming a crystalline salt with silver: this acid is isomeric with pyrogallic acid. *Cholic acid* in fine needles is obtained by boiling bilic acid or bile with caustic soda, and precipitating the acid by acetic acid. By NO_5 it is converted into cholesteric acid. In the bile we find a pearly substance, melting at 279°, soluble in

ether and boiling alcohol, *Cholesterin* ($C_{36}H_{22}O$), which sometimes collects in the gall bladder in the form of calculi. Bile appears to be entirely reabsorbed in the intestinal canal, as none of it exists in the fæcal matter; and when injected into the rectum it disappears, and does not return. It is most probably derived from the casein, albumen, or fibrin of the food, and possibly, in the inferior animals, partly from the starchy matter. The bile possesses all the character of a soap, and is used as a detergent for cleaning floors. *Lithofellic* acid ($C_{40}H_{35}O_5$), a crystalline substance, derived, by means of soda and HCl, from *bezoar* stones, concretions supposed to be voided by deer in the east. One of the bezoars in the Glasgow Museum has for a nucleus a date stone. *Nitro-lithofellic* is formed by the action of NO_5. *Bezoaric* acid or eleagic acid of nut-galls is also found in some bezoars. A large portion of the matter taken into the stomach is expelled by the rectum, in the form of excrement. This consists in cows, when fed on grass, of a green matter, containing about 86 per cent. of water, and 14 of solid matter. When digested in ether, the green colouring matter is removed, and chopped hay remains. In the human excreted matter we find 75 per cent. of water, the solid residue containing 14 per cent. of ash (phosphate of lime, sulphate of lime, silica, &c.), and the rest being mucus and excess of food. The peculiar odour may be imitated by heating curd with solid potash in a retort, to expel NH_3, and saturating the potash with SO_3; on distilling an acid liquor passes over, possessing this peculiar smell. The fæculent matter of animals contains only insoluble salts, and is therefore the least important kind of manure. It is comparatively useless unless mixed with the soluble salts (phosphates, sulphates, and muriates of the alkalies) of the urine.

3. *Sanguification* or *Formation of Blood.*—The primary stage of digestion being completed in the intestinal canal, the chyle or digested matter, a milky fluid, is absorbed, partly through the lacteals (from their containing a milky fluid), and probably the veins, and makes its way by the thoracic duct, or veins, into the general circulation. When fat enters into the composition of the food, it may be detected soon after it is swallowed in the watery part of the blood. The thoracic duct, in which all the lacteals terminate, passes up the right side of the spine, and terminates in the superior vena cava vein, when the chyle of the lacteals is poured into the current of the circulation, and passes to the right auricle of the heart, and from thence to the right ventricle. From the last cavity it goes, by the pulmonary or lungs artery, to be distributed on the walls of the cells of which the lungs consist, in order to be purified by the oxygen of the air, and to part with the carbonic acid with which it is charged. The pulmonary arteries terminate in pulmonary veins, and carry the purified blood into the

left auricle of the heart; thence into the left ventricle and aorta, or large artery, by which it is distributed to all parts of the body. The blood is supposed to contain a small amount of all the substances existing in the body, and of these a number have been already detected. When the blood is drawn from a living animal it is fluid, but on standing, a clot subsides, and a liquid portion or amber-coloured serum floats above. The following is a list of the substances found in 1000 parts of blood from the human veins.

Clot.					
	Fibrin			3·00	
	Globules consisting of colouring matter and globulin			124·78	
	Casein				
Serum.					
	Albumen			69·41	
	Water			785·59	
Gases	Carbonic acid. Nitrogen. Oxygen.				
Fats.	Cholesterin			6·5	
	Serolin?				
	Olein				
	Margarin				

Serum — *continued.*		
Salts.	Chloride of sodium	10·72
	——— potassium	
	——— ammonium	
	Carbonate of soda?	
	——— lime?	
	——— magnesia?	
	Phosphate of soda	
	——— lime	
	——— magnesia	
	——— iron	
	Sulphate of potash	
	Lactate of soda?	
	Fatty acid salts	
	Volatile fat salts	
	Yellow colouring matter	
	Sugar	
	Urea	
	Uric acid — (*Garrod*).	

In diseases the blood varies in its composition from the natural standard, as is ascertained by *analysis*. The amount of water in the blood is ascertained by evaporating a weighed portion of it to dryness by a steam heat. The fibrin is obtained by beating a portion of the blood with a stick, throwing it on a towel, and washing it with a stream of water, and drying the fibrin at 212°. The *albumen* is obtained by squeezing out the serum from the clot, and coagulating the whole serum by heat, washing and drying. The remainder of the clot consists of globules and salts. The latter are obtained by calcination. The fatty substances are obtained by treating the dried clot with ether; the casein, by treating the moist clot with boiling alcohol. 1. In inflammatory diseases the fibrin increases. 2. In typhoid fevers the fibrin neither increases nor diminishes. 3. In anæmia, or disease proceeding from deficiency of blood, the globules diminish. 4. In Bright's disease of the kidney the albumen diminishes, and passes into the urine.

4. *Nutrition.* — The blood is carried up by the aorta and carotid arteries of the neck to the head, where it deposits the brain, the organ of thought. This essential part of intelligent beings occupies the cavity of the head or skull, and

consists of a soft mass, which speedily undergoes decomposition when exposed to the air. The brain consists of 78 per cent. of water, albumen 7; cerebric acid, oleophosphoric acid, cholesterin, olein, margarin, oleic and margaric acids 9·85; soda, phosphate of soda, potash and magnesia, common salt, 5·15. The water is estimated by drying the brain at 212°. If it is then treated with cold ether, oleophosphoric acid, cholesterin and olein are taken up, while cerebric acid and albumen remain. The cerebric acid is taken up by hot alcohol.

Oleophosphoric Acid. — A viscid yellow fatty substance, resembling olein, swelling up a little in boiling water; insoluble in cold alcohol, but readily so in boiling alcohol. Soluble in cold ether. When long boiled in water, decomposes into olein and PO_5. The softening of the brain may be owing to this separation. It may be purified from olein by absolute alcohol, which dissolves olein but not this acid. It may be obtained from the brain by treating it with hot ether. On cooling, cerebrate of soda and oleophosphate of soda separate. These are to be dissolved in hot alcohol, acidulated with SO_3. On cooling, the two acids separate; oleophosphoric acid dissolves in cold ether, while cerebric acid remains. *Cerebric acid.* — White crystalline grains (C 67·04 N 2·24 H 10·85 P 0·40 O 19·41), insoluble in cold, soluble in hot, ether; insoluble in cold, soluble in hot, alcohol. Swells up like starch when boiled with water. It may be obtained from brain by digesting in weak caustic potash, drawing off the liquid which separates, and washing with water, and decanting by a syphon, decomposing the soap by tartaric acid, and repeatedly crystallizing out of boiling alcohol or ether. It is also obtained by heating the dry brain with ether, dissolving in acidulated boiling alcohol to remove bases, and heating the precipitate, on cooling, with cold ether. Oleophosphoric acid dissolves, and leaves cerebric acid, which may then be purified by frequent solution in boiling alcohol or ether. All these substances may be separated from cholesterin by boiling alcohol. The spinal marrow and nerves have a composition similar to that of the brain.

Muscle. — By a similar action to that of the deposition of the brain, a certain amount of muscular substance in the body is deposited daily. There is some difficulty in understanding how the fibrin, which is dissolved in the blood, should be deposited by the extremities of the arteries in a solid form, but the observation that certain forms of lymph or fluid, secreted by serous membranes, do not deposit fibrin when left to themselves, but become almost solid when a piece of fibrin is introduced into them (*Dr. A. Buchanan*), seems to throw some light on the process of nutrition, and the deposition of flesh from the blood. Blood and flesh, when analysed, appear to have the same ultimate

composition. Flesh, however, contains a number of soluble substances. *Analysis of flesh.*—When the flesh of animals is cut into pieces, mixed with water in a stout bag, and subjected to pressure, a fluid exudes, which is strongly acid, owing to the presence of lactic acid, and in solution there is found 5 per cent. of matter dissolved. By heating up to 140°, 2½ per cent. of albumen separates, and is to be filtered. The liquid is saturated with barytes water, as long as a precipitate falls, of phosphate of barytes, filtered, evaporated in a water bath at 140°, and carbonate of barytes filtered off. When reduced to a syrup, and set aside, there separate crystals of *Creatine* (C_8 N_3 H_{11} O_6), brilliant needles, soluble in 7 parts of hot water, in 75 parts of cold water, sparingly soluble in alcohol. The largest amount of creatine is 3·2 per 1000 in the fowl; the smallest 0·6 in the skate. (*Gregory.*) When HCl is heated with creatine, it is resolved into a new base (*Creatinine* C_8 N_3 H_7 O_2), united with HCl, from which the base may be separated by boiling with hydrous oxide of lead. It is in prisms, soluble in 11 to 12 cold water, 100 of alcohol; it is a strong base, expelling NH_3; it forms crystalline compounds with $AgO\ NO_5$, Zn Cl, Pt Cl_2. *Sarcosin* (C_6 NH_7 O_4), right rhombic prisms; soluble in water, scarcely so in alcohol; insoluble in ether, decomposed above 212°; obtained by boiling creatine with barytes water; it is a base, uniting with acids, and is formed from creatine by the separation of urea; it has the same composition as lactamide and urethane. The juice of flesh contains *inosinic acid*, which is found in the fluid after separating creatine. To the syrup alcohol is added; the deposit is dissolved in warm water, and Ba Cl added. On cooling, inosinate of barytes is deposited in white silvery scales, decomposed by boiling; the acid consists of C_{10} N_2 H_6 O_{10}. Phosphate of potash ($2KO\ HO\ PO_5$), an acid salt, exists in muscle, whereas phosphate of soda exists in the blood; and hence it appears that the membranes prevent the direct interchange of the salts, otherwise they would be equally distributed over the body. The soda phosphate of the blood increases the solubility of CO_2, which is not the case with the corresponding potash salt; and so necessary is the soda phosphate to the blood, that if the food contains only the potash phosphate, it decomposes the common salt, and forms a soda phosphate (*Liebig*). Flesh consists of water 79; fibrin and cellular matter 17; albumen 3; and lactic acid, phosphoric acid, fat, creatin, inosinic acid, phosphate of potash, phosphate of soda, phosphate of lime, phosphate of magnesia, K Cl and Na Cl. It is possible that the transformation of the flesh into the soluble *urea* found in the urine, commences by the production of the above substances. There is another body extensively formed in the ligaments and cellular tissue, *gelatin* or *glue, isinglass* (C 50·5 H 6·9 N 18·47 S ·56 O 23·57); brown or

colourless, soluble in water, precipitated by nut-galls and tannic acid, when leather is formed. When boiled with potash or SO_3, *glycycole* or *glue sugar* ($C_4 NH_5 O_4$) in crystals, soluble in water, insoluble in alcohol, and ether is obtained, uniting with acids and forming crystalline salts. All these substances, except the last, are present in soups, in which some are decomposed by long boiling. *Beef tea* is best made by mincing 1 lb. of beef very fine, with its own weight of cold water, brought to the boiling point, then strained and tinged with roasted onions or burnt sugar. *Boiled beef* should be made by introducing the meat into boiling water; a coagulum of albumen forms round the exterior, which prevents the juices from passing out, in which fluid the latter is more soluble than the others.

5. *Secretion of Substances from the Blood. Milk.*—The aorta gives off the subclavian artery, from which proceeds the mammary arteries — the secretors of the milk in the female breasts. Milk is a familiar white fluid, in which small round globules are observed to float by the aid of the microscope. After standing for some time an oil collects on the surface, termed *Cream*, which consists of butter and curd. When an acid or alcohol is dropped into milk it curdles, by the separation of casein, already described (p. 167.), and by heat albumen coagulates. The composition of cow's milk, under a grass diet, is water 87·19; butter 3·70; sugar 4·35; casein 4·16; soluble salts, containing principally potash, 0·15; insoluble salts 0·44; specific gravity 1030. Butter and albumen are separated from the milk by agitating the cream or milk in a churn; the milk becomes sour by the production of lactic acid at the expense of the sugar, and the acid curdles the casein, the butter being set free; the temperature of the milk rises some degrees. Butter consists of 12·79 water; butter 86·27; casein 0·94; and in consequence of the presence of the curd it is liable to become rancid, or decompose. It may be preserved by beating it in a pan till all the water is dissipated, and then pouring off the oil from the curd, and keeping it in close vessels. Human milk has less sugar than cow's milk. To convert the latter into the former we require to add some water and sugar. The sugar of the milk appears capable of being formed from nitrogenous matter alone, as it occurred in the milk of a dog fed exclusively on flesh. The sugar of milk, or lactin, is peculiar ($C_{24} H_{24} O_{24}$), as, when treated with NO_5, it gives oxalic acid and mucic acid: common sugar only yields oxalic acid. The acids of butter have been already described (p. 202.). It may simply be stated, that by saponifying butter with potash or soda, and treating the soap with tartaric acid, margaric and some oleic acid rise to the surface, while capric, caproic, caprylic, and butyric acids remain in the liquor. By filtration the margaric and oleic acids are separated, while the

other acids pass through, and may be distilled over. They are then separated in the manner previously described.

Analysis of Milk. — Evaporate to dryness at 212° for the water; take up the butter by ether, then the soluble salts and sugar by water, burning away the sugar to procure the soluble salts. The residue consists of casein and insoluble salts. Ignition removes the casein and leaves the insoluble phosphates.

Urine. — The aorta descending along the left side of the spine gives off in the abdomen the renal or emulgent arteries to the kidneys, the organs by which the urine is separated from the blood. From the kidneys the urine passes by the ureters, to the bladder. The urine, when healthy, has a pale yellow colour, and is perfectly clear, without any deposit; the acid reaction is considered by Liebig to be owing to the presence of hippuric acid and uric acid, dissolved by phosphate of soda; specific gravity, from 158 observations, I have found 1019. The average quantity daily, for six weeks in winter, is 50½ fluid ounces. The composition of healthy urine is nearly as follows: —Water, 933; urea, 30·10; sulphate of potash, 3·71; sulphate of soda, 3·16; phosphate of soda, 2·94; chloride of sodium, 4·45; phosphate of ammonia, 1·65; sal ammoniac, 1·5; hippuric acid and animal matter undefined, 17·14; earthy phosphates, 1·0; uric acid, 1; mucus, 0·32; silica, 0·03; the animal matter includes acetic acid (*Thomson*, 1824), creatine, creatinine, and hippuric acid. In some diseases the amount deviates from the healthy standard; the healthy daily quantity being 1·3 lbs.; in rose, fever, &c. it is 1·5. In chlorosis 2·7lbs. Disease of the liver 2·83lbs. In diabetes the amount of urine is enormous, sometimes 70lbs. per day; the specific gravity being high, from 1030 to 1054. In this disease sugar is present in large quantity, which may be detected by adding a little bile to the urine, and then SO_3; a fine red colour is produced. In Bright's disease the urine contains albumen, which may be detected by adding a few drops of NO_5, and then heating; the albumen is coagulated. I have extracted half an ounce and upwards of albumen from the urine passed in twenty-four hours in this disease. In the healthy state, after some irregularity, a *buff* precipitate of urate of ammonia often appears in the urine after standing, which is soluble in hot urine. When there is inflammatory action in some internal organ, a *red* sediment forms of urate of NH_3, mixed with purpurate of NH_3. In chronic diseases of the bowels, in hectic and irritative fever, a *pink* precipitate falls. 1. *Uric acid* calculi sometimes form in the form of stones, and give rise to serious disease. They have generally a smooth surface, and are distinguished by dissolving in NaO, in NO_5 with effervescence, and yielding a fine purple with NH_3. 2. *Oxalate of lime*, or mulberry calculus, a rough stone, soluble without effervescence in NO_5, becomes

caustic lime by heating; occurs also in many skin diseases, and can be detected in crystals in the urine (*Prout*). They occur also in plants. 3. *Triple phosphate* of MgO and NH_3, white; not stratified; gives off NH_3 by heat, and NaO; very soluble in dilute acids, the solution being precipitated by NH_3. 4. *Fusible calculus* of CaO PO_5, *triple phosphate* of MgO and NH_3 white, and friable like chalk; fuses before the blow-pipe. 5. *Urate* of NH_3; clay colour, decrepitates by heat, evolves NH_3 by NaO, soluble in alkaline carbonates. 6. *Urate of soda*, or *chalk stones*, yielding common salt to HCl, occur in the joints in gout. 7. *Phosphate of lime*, soluble in acids, solution precipitated by NH_3. 8. *Xanthic oxide* (C_{10} H_4 N_4 O_6) gives a lemon-yellow solution with NO_5. 9. *Cystic oxide*, yellowish-white, dissipated by heat, soluble in acids and alkalies: it contains sulphur. Large concretions formed of hair and husks, mixed with phosphate of lime, often occur in the intestines of animals.

Testing Calculi. — They may be divided into two classes; some being soluble, and others insoluble, in caustic potash and soda. — I. Soluble in caustic potash. 1. *Uric acid*, precipitated by acids. 2. *Urate of ammonia*, soluble also in alkaline carbonates. 3. *Cystic oxide*, soluble also in carbonates. 4. *Xanthic oxide*, solution in potash precipitated by CO_2. — II. Insoluble in caustic potash. 1. *Phosphate of lime* or *bone earth*, insoluble in acetic acid; fuses with difficulty. 2. *Ammonia phosphate of magnesia*, soluble in acetic acid and NO_5. 3. *Fusible calculus*, partly dissolved by acetic acid, and the rest by HCl. 4. *Oxalate of lime*, decomposed by carbonate of potash, oxalate of potash being dissolved; insoluble in acetic acid. The blowpipe renders it caustic, which renders water alkaline. 5. *Carbonate of lime*, soluble with effervescence in acetic acid.

As a Manure. — The salts of the urine being those which belong to the food that has been converted into blood, it is obvious that they are exactly calculated to restore to land those substances which have been removed by the nutritive part of the crop. When an animal is grazing in a field, it removes nothing from the soil which it does not return. Hence, if the farmer feeds his cattle on the whole of the crops which he removes from his fields, and throws back the whole of the straw and grain in the form of dung (or straw bedding, urine and excrement), his farm will ultimately not become impoverished. But if he sells any portion of his grain, or straw, or stock, he must restore the waste of his soil by manure from foreign sources — such as guano — which is the urine of sea birds.

Analysis of Urine. — The water is obtained by evaporating a weighed quantity at 212°; the uric acid, by adding a few drops of H Cl to a weighed quantity, and allowing it to stand for 24 hours. Crystals separate on the sides of the vessel, which are

filtered and weighed. The urea is obtained by evaporating to a syrup, and adding an equal bulk of NO_5; nitrate of urea falls, which is filtered. The various salts are estimated by methods already pointed out. Hippuric acid is obtained by evaporating to a syrup; adding H Cl, and then ether, the acid is taken up.

6. *Respiration and Skin Exhalation.* — All the matter introduced into the stomach finally disappears from the body by the urine, in a liquid form, by the lungs in a gaseous form, or by the skin in a gaseous and fluid state. The surface of the intestinal canal must therefore be related to these exhaling surfaces. The idea at present entertained is, that starch and sugar and fat are conveyed to the blood, and give out heat on being converted and expelled, as CO_2, by the action of the oxygen of the air. The amount of oxygen taken into the lungs daily by an adult man is calculated at 2 imperial pounds, and of the carbon thrown out as CO_2 at $13\frac{8}{10}$ ounces. The CO_2 may be detected by breathing through a tube dipping into lime water; carbonate of lime falls. These substances it is not supposed pass immediately into the gaseous condition, but through intermediate stages by the substitution of oxygen for hydrogen, as follows (*Liebig*).

$$\underset{\text{Starch.}}{C_{12}H_{10}O_{10}} \quad \underset{\text{Grape sugar.}}{C_{12}H_{12}O_{12}} \quad \underset{\text{Lactic acid.}}{2\begin{pmatrix}C_6 H_6\\ O_6\end{pmatrix}} \quad \underset{\text{Carbonic acid.}}{2\begin{pmatrix}C_6 O_6\\ O_6\end{pmatrix}}$$

The nitrogenous substances are destined to supply daily the place of a certain quantity of similar matter, previously deposited in the flesh, brain, &c. Every movement of the limbs, every glance of the eye, every thought that flits across the mind, is accompanied with the transformation of a certain amount of nitrogenous matter into a soluble form to be ultimately expelled from the system in a liquid or gaseous state. Such changes are accompanied with the evolution of heat; but so slowly, that much exercise must be employed to keep up the heat of the system. Hence it is that the North American Indians, who live solely on animal food, are compelled, by their physical structure, to lead a wandering and predatory life. The first step in their civilization must be their becoming agriculturists, and using, in addition to flesh, starchy food, to supply a more accessible form of animal heat. There ought, however, to be a definite relation between the amount of nitrogenous or nutritive matter swallowed, and that of the starchy or calorifiant (heat producing matter), because it is obvious that, when the digested food is presented to the mouths of the lacteals, which take it up from the intestine, it will be absorbed just as it comes forward to these apertures, since they have no power of selecting one kind of soluble matter and rejecting another. If these vessels possessed such a faculty of preference, it is obvious that they would reject poisons,

which we know they have no power of doing. Hence a proper diet must consist of that in which the nutritive matter is properly proportioned to the calorifiant matter, under the circumstances in which an animal is placed. Thus an animal taking violent exercise must displace a larger amount of muscular matter or flesh than another in a state of rest. The food for this animal must therefore contain more nitrogenous or nutritive substances; and, as a general rule, it is certain that the only true theory of dieting must depend on ascertaining the exact amount of each kind of matter displaced under different conditions of exercise, and supplying the substances removed in the food, just as in the true theory of manures for vegetables, it is necessary to discover by experiment what are the substances removed by different kinds of grain from the soil, and to supply these in the form of manure. A stall-fed cow, weighing about 1000lbs., takes into its blood 1½lbs. daily of nitrogenous matter, and 13lbs. daily of starch or sugar (calorifiant food). As the animal does not augment in weight, it is obvious that an equal amount of matter must have been removed daily from the system.

I have elsewhere endeavoured to develope this law, by pointing out the relations between these constituents of the food in the milk, the natural food of the young (*Experimental Researches on Food*, p. 167.), and then comparing it with the food usually employed by men and animals. In cow's milk the nutritive matter is related to the calorifiant matter as 1 to 2; in the human milk as 1 to 6; and the reason of this difference is obvious. The calf soon after being born often begins to walk, and to consume muscle in a greater degree than the child, which is comparatively inert in its muscular system for months. A cow, stall-fed, and therefore at rest, consumes 1 part of nutritive matter for 8½ of calorifiant matter; and wheat, barley, and some other grains are constituted in the relation of 1 to 8. It may therefore be inferred from this and other facts, that an animal undergoing exercise should use food containing a larger amount of nutritive matter than is contained in wheat, flour, and barleymeal: and hence the reason for the use of animal food to labouring men. Upon the same principle the use of sago, arrow-root, and tapioca, for feeding children is highly objectionable and dangerous. We might expect these descriptions of food, if used exclusively, to produce *scurvy*, as by the process for preparing them, all nitrogenous matter and soluble salts are removed. It is in consequence of the removal of the soluble salts from beef in salting that the production of scurvy at sea depends (*Liebig*). The cure for this disease is lime juice, which I find to contain alkaline phosphate, sulphate, chloride, phosphate of lime, the very salts which are removed from salt beef. Restriction to one kind of

food is apt to produce scurvy, in consequence of the absence of some ingredient which would be supplied by a mixed diet, as in this country, from the inclemency of the season, few of the crops are perfectly formed. Those which contain much water resist the atmospheric influence most effectually, and hence succulent vegetables, from their containing the soluble salts necessary for the blood, are used for the cure of scurvy. After the preceding law had been pointed out, Dr. Knapp calculated the result of an experiment made by Liebig, on a company of soldiers, and found that the relation of the nutritive to calorifiant matter used by them was 1 to 4¾. The calorifiant matter is principally expelled in the form of carbonic acid and vapour of water, by the lungs; the latter also by the skin. The carbonic acid appears to be formed throughout the whole circulation, and the heat evolved by the chemical action which occurs during its formation is thus diffused over the system. The heart is the force pump which sets the circulation in motion — the nerves, again, assist in keeping up this action; but, as in the galvanic battery, it is to the chemical action of the union of the oxygen of the air with the carbon and hydrogen of the digested food that we must look for the primary spring or force upon which the whole movements of the apparatus depend.

To preserve the human system in a healthy condition — that is, to have the heart and pulse beating regularly, the stomach digesting the whole of the food taken, the lungs throwing out a quantity of air, containing from 3·5 to 4 per cent. carbonic acid — it is necessary that the food should have its constituents properly equalized. If there should be a deficiency of either the nitrogenous matter or heat producing matter or salts, the blood must be formed without the proper proportion of each ingredient, and an unhealthy fluid circulating in the system must thus be generated. Now as infectious diseases do not equally attack all individuals, it is obvious that one set of persons must, from the constitution of their blood, be more liable to an attack than others. The state of the system thus produced which affords such easy access to disease, can only be altered by a regulation of diet, and can never be removed by empirical purgation — the parasite of medical ignorance. One class of diseases — as ague, Asiatic cholera, influenza — is apparently dependent on emanations from the earth, or the local state of the atmosphere; but is not communicable from one person to another, and may be radically extirpated by drainage and proper treatment of the soil. Another class, as small-pox, measles, plague, typhus, is communicated to different individuals by a poison generated in the animal system, and which can re-produce itself at the expense of some of the ingredients of the blood. These diseases can often be anticipated in a modified form, by the inoculation of the system with the disease when it is in

a healthy condition, and by removing the healthy from contact with the diseased. This form of poison does not appear capable of travelling through the air like that of cholera and influenza. When brought in contact with chlorine, alcohol, sulphurous acid, and when exposed to a temperature even considerably under the boiling point of water, it is rendered inert. According to the opinion of some, the poison of typhus and yellow fever appear capable of passing into the atmosphere in a finely divided state, resembling vapour, and of thus disseminating their influence, and entering into the blood of those exposed to its action. The poison, or seed, will only take effect, however, in a congenial soil; that is, in diseased blood — as in those who have been imperfectly fed, or who have been weakened by over exertion; by an impure diet, or by alcoholic fluids, which interfere with digestion, and debilitate the entire system.

EXPLANATION OF CHEMICAL TERMS.

A.

ABSORPTION — (*ab* from, and *sorbeo*, I suck up). The entrance of one body between the particles of another, as water into a sponge.

ACID. A body which unites with a base.

AFFINITY — (*ad*, and *finis*, allied to). An attraction between two or more bodies.

ALCOATE. A combination of alcohol.

ALLOTROPY (αλλος, another, τροπος, habit). A body having different physical characters; as carbon in its four forms.

ALLOY. A compound of two or more metals.

AMALGAM. A compound of mercury and another metal.

ANALYSIS — (ανάλυσις). Resolution, or a loosing of the constituents.

ANHYDROUS. Destitute of water.

ANNEALING. The process of removing the brittleness from glass.

AQUA REGIA. A mixture of 1 part Nitric, and 2 parts Chlorohydric acids.

AQUEOUS. Watery.

ATMOSPHERE (ατμος, vapour, and σφαιρα, a sphere).

ATOM. The smallest ultimate particle of matter.

B.

BALANCE. An apparatus for determining the weights of substances.

BAROMETER (βαρυ, heavy, μετρον, a measure). A measurer of the weight of the air, fig. 60.

BASE. A body which unites with an acid.

BASINS. Vessels, more or less deep, for evaporation: of *porcelain*, *glass*, and *metal*.

BATH. A vessel, containing generally a fluid, which is so arranged as to heat a substance. They may be mercurial, water, steam, or sand.

BLOWPIPE. A tube for propelling the flame of a candle or lamp horizontally.

C.

CAOUTCHOUC. Indian rubber, an exudation from certain trees.
CAPILLARY-TUBE. A tube of such small bore as to resemble the diameter of a hair (*capilla*).
CAPSULES. Small basins or vessels of porcelain, glass, or platinum, &c.
CATALYSIS (κατα, from, λυω, I loose). An action of contact or surface.
CEMENT. A composition for causing two bodies to adhere; as Parker's, iron, soft.
CENTIGRADE, or *Celsius*. Thermometric scale, in which the freezing point is 0° and boiling point 100°. — To reduce Centigrade to Fahrenheit, multiply by 1·8, and add 32. Thus 50 C × 1·8 = 90·0 + 32 = 122° F.
CHARCOAL. The residue from the ignition of wood in close vessels or under cover.
CHEMICAL ACTION. The insensible action of one atom of matter on another.
COKE. The carbon remaining when coal is burnt in close vessels.
CONDENSATION. The conversion of a gas into a liquid.
CORK BORERS. Cylinders of tin for cutting corks.
COVERS. The lids of vessels.
CRUCIBLE. A vessel for withstanding intense heat, formed of platinum, silver, porcelain, clay, iron, or charcoal.
CRYSTAL. A definite form.
CUBIC INCH BOTTLE. For measuring the bulk of fluids, and taking specific gravities.

D.

DECANT. To pour off a fluid from a residue.
DECOCTION. The water which has been boiled with an organic substance.
DECOMPOSITION. A radical change in the composition of a body.
DECREPITATION. The peculiar sound produced when common salt is heated, arising from the sudden extrication of water.
DEFLAGRATION. The luminous decomposition of a body by heat; as when nitre is thrown on red hot coals.
DENSITY. Specific weight or gravity, fig. 7.
DEOXIDATION. The removal of oxygen.
DESICCATION. The operation of drying thoroughly.
DETONATION. An explosion.
DIAMOND-CUTTER. Fragments of diamond made into a paste for cutting glass.
DIGESTION. The process of allowing a solid to remain in contact with a fluid, in order to dissolve some portion of it.
DIMORPHISM. A body having two crystalline forms.

DISCOLORATION. The removal of colour.
DISTILLATION. The evaporation and condensation of a fluid by heat.
DROPPING TUBE. Sucker or pipette for sucking up fluids.

E.

EARTHENWARE. A mixture of clay and flint, used for making vessels.
EBULLITION. The act of boiling.
EDULCORATION. The act of washing free from salts.
EFFERVESCENCE. The rapid escape of a gas, as when vinegar is poured on chalk.
ELECTROMETER. A measurer of electricity.
EQUIVALENT. The relative weight of the ultimate particles of matter.
EREMECAUSIS. Slow combustion, as the rotting of trees by the formation of carbonic acid and water.
EUDIOMETER. A tube for exploding gases in.
EVAPORATION. The conversion of a liquid into vapour.

F.

FAHRENHEIT'S THERMOMETRIC SCALE. The boiling point 212°; the freezing point 32°. To bring Fahrenheit to Centigrade, subtract 32, and divide by 1·8. Thus 122° F. − 32 = 90 ÷ 1·8 = 50° C.
FILTERING PAPER. Unsized white paper.
FILTRATION. The act of passing a fluid through a filter.
FLASKS. Thin glass bottles made to stand heat.
FLUX. A substance which when heated with another forms a glass, as borax, nitre, black flux, &c.
FOIL. Thin leaves of metal.
FORMULA. A concise method of expressing the composition of a body. SO_3 is the *empirical*, $SO_2 + O$, the *rational* formula for sulphuric acid, as expressing the mode of its decomposition.
FUEL. A substance which gives out heat when burned.
FUNNELS. Conical vessels of glass for the support of filters.
FURNACE. An enclosed fire-place of brick, earth, or iron.

G.

GAS. Any species of air, or elastic fluid.
GASOMETER. A fluid measurer or holder of gases.
GAUGE. A measure, as a rain gauge.
GRADUATION. The act of dividing into degrees.
GRANULATION. Conversion into grains.
GUTTA PERCHA. An exudation from a tree (*Isonandra gutta*).

H.

Hydrometer. A measurer of the density of fluids.
Hygrometer. A measurer of the quantity of moisture in air.
Hydrate. A compound of water and another body, (ὑδωρ, water.)
Hydrous. Applied to a body containing water.
Hydracids. Acids containing an element with hydrogen.

I.

Ignition. The act of exposing to a red heat.
Infusion. A solution of a substance by digestion in water.
Insolubility. Refusal to be taken up by fluids.
Insulation. Separation by itself.
Isomorphous. Bodies having the same crystalline form, and capable of replacing each other.
Isomeric. Bodies having the same formula.

J.

Jars. Vessels of glass or earthenware.
Joints. The meeting points of tubes.

L.

Lamps. Vessels for burning oil, alcohol, gas, for the application of heat.
Leyden Jar. A glass vessel for collecting electricity.
Liquefaction. The conversion into a fluid.
Litmus Paper. Paper coloured with an infusion of litmus, a blue colour.
Lixiviation. The act of dissolving salts.
Lutes. Pastes for connecting tubes.
Lye. A solution of caustic alkalies or soap.

M.

Maceration. The act of steeping.
Magnetism. The property which iron may be made to assume of pointing to the north and attracting iron.
Melting. The act of a solid becoming fluid.
Mortar. An instrument of agate, marble, earthenware, iron, or steel, for grinding powders.
Muffle. A clay vessel for oxidating metals by heat.

N.

Neutralization. The action of rendering a solution neither acid nor alkaline.

O.

Oxacids. Acids consisting of an element united with oxygen.
Oxide. A combination of oxygen with a body.
Oxidation. The act of forming an oxide.

P.

Pestle. An instrument to beat in a mortar.
Phosphorescence. The act of glowing like phosphorus or putrid fish in the dark.
Pneumatic (*πνευμα*, a spirit.) Of or belonging to gases.
Pulverize. To reduce to powder.
Pyrometer. A measurer of high temperatures.
Polymorphous. Having several crystalline forms.
Polymeric bodies. When the formula of one body is a multiple of another by 1, 2, or 3, &c., they are polymeric.

R.

Radical. A base or root of compounds.
Reaumur's thermometer. —Boiling point, 80°; freezing point, 0°. To reduce Reaumur to Fahrenheit, multiply by 2·25 (2¼), and add 32. Thus 40° R. × 2·25 = 90· + 32 = 122° F. To reduce Fahrenheit to Reaumur, subtract 32 and divide the remainder by 2·25.
Receiver. A vessel for receiving distilled fluids.
Rectification. Frequent distillation.
Refrigeration. The act of cooling.
Reflection. The bending back of a ray of light or heat.
Residue. The remainder.
Retort. A vessel for distilling, fig. 15.

S.

Safety tube. A tube for the admission of common air in distillation.
Saturation. As much as a body can take up.
Solution. The act of dissolving.
Solvent. A body which dissolves another.
Spatula. A flat instrument of platinum, or porcelain, &c., for stirring.
Specific gravity. Peculiar weight, p. 7.
Still. A metallic vessel for distillation.
Stopcock. A valve to close and open a vessel.

SUBLIMATION. To raise up a solid by heat.
SUCKER. A tube for sucking up fluids, fig. 29.
SYPHON. A bent tube for conveying fluids from one vessel to another, fig. 86.
SYNTHESIS (*συνθεσις*). Formation of a body from its elements.

T.

TEMPERATURE. The state of heat.
TESTING. The application of tests, or reagents.
THEORY. From *θεωρια*. Mode of seeing; explanation.
THERMOMETER. A measurer of heat.
TRITURATE. To rub together.
TROUGH. A vessel for holding water or mercury in examining gases.

V.

VALVE. A lid or door opening in one direction in a tube.
VAPOUR. The gaseous or elastic form of a fluid.
VENTILATION. The removal of noxious gases from the atmosphere, and introduction of pure air.
VOLTAIC BATTERY. An arrangement of a series of two metals for producing electricity.
VOLUME. A measure.

W.

WEIGHING. The act of determining the weight of a body.
WORM TUBE. A tube bent like a worm, for condensing distilled fluids.
WOULFE'S BOTTLES. Vessels with three openings for condensing gases in water, &c.

APPENDIX.

TABLES OF THE STRENGTH OF ACIDS, &c.

Amount of dry Acid in 100 *Parts.*

Nitric Acid.		Chlorohydric Acid. *E. Davy.*		Sulphuric Acid. *Ure.*	
Sp. Grav.	Acid p. c.	Sp. Grav.	Acid p. c.	Sp. Grav.	Acid p. c.
1·522	86·0	1·21	42·43	1·8485	81·54
1·498	84·2	1·20	40·80	1·8475	80·72
1·478	72·9	1·19	38·38	1·8460	79·90
1·434	62·9	1·18	36·36	1·8439	79·09
1·422	60·0	1·17	34·34	1·8410	78·28
1·376	51·9	1·16	32·32	1·8376	77·46
1·353	48·7	1·15	30·30	1·8336	76·65
1·300	40·6	1·14	28·28	1·8290	75·83
1·283	38·5	1·13	26·26	1·8233	75·02
1·252	34·2	1·12	24·24	1·7774	70·12
1·234	31·8	1·11	22·22	1·6415	60·34
1·215	29·5	1·10	20·20	1·5066	50·55
1·152	21·5	1·09	18·18	1·3884	40·77
1·122	17·5	1·08	16·16	1·2826	30·98
1·105	15·14	1·07	14·14	1·1792	20·38
1·0708	10·36	1·06	12·12	1·1330	15·49
1·0485	7·17	1·05	10·10	1·0887	10·60
1·0375	5·58	1·04	8·08	1·0405	4·89
1·0212	3·18	1·03	6·06	1·0268	3·26
1·0159	2·39	1·02	4·04	1·0140	1·63
1·0053	0·79	1·01	2·02	1·0074	0·815

Ammonia.		Ammonia.	
Sp. Grav.	Gas p. c.	Sp. Grav.	Gas p. c.
0·8720	32·5	0·9435	14·53
0·8875	29·25	0·9476	13·46
0·9000	26·00	0·9513	12·40
0·9054	25·37	0·9545	11·56
0·9166	22·07	0·9573	10·82
0·9255	19·54	0·9599	10·17
0·9326	17·52	0·9619	9·60
0·9385	15·88	0·9692	8·50

Alcohol. — *Dr. Steel.*

Amount of absolute Alcohol in 100 *Parts.*

Sp. Grav.	p. c.	Sp. Grav.	p. c.	Sp. Grav.	p. c.
·7964	100·	·8475	80·	·9713	20·
·7956	99·5	·8597	75·	·9774	15·
·7971	99·	·8717	70·	·9838	10·
·7984	98·5	·8835	65·	·9852	9·
·7997	98·	·8952	60·	·9912	5·
·8023	97·	·9066	55·	·9920	4·5
·8049	96·	·9179	50·	·9928	4·
·8075	95·	·9287	45·	·9946	3·
·8101	94·	·9391	40·	·9963	2·
·8127	93·	·9487	35·	·9972	1·5
·8210	90·	·9574	30·	·9981	1·
·8349	85·	·9649	25·	·9990	0·5

INDEX.

A

Page

Acetal - - 176
Acetates - - 177
Acetone - - 177
Acid, acetic - 176
acrylic - 182
adipic - 203
aldehydic - 176
aconitic - 198
amygdalic - 179
antimonious 102
antimonic - 102
arsenic - 101
arsenious - 98
azoleic - 203
benzilic - 180
benzoic - 179
bilic - - 211
boracic - 86
bromic - 46
butyric - 203
cacodylic - 178
capric - 204
caproic - 204
carbonic - 74
cerotic - 205
chloracetic - 177
chlorisatic - 195
chlorochromic 104
chlorohydric 58
chromic - 103
chrysanilic - 196
citraconic - 198
citric - - 198
comenic - 199
cochnic - 204
crotonic - 204
cuminic - 205
cyanohydric 83
cyanuric - 82
cyanic - 82
ellagic - 199
elaidic - 203
ethalic - 204
ethionic - 177
formic - 162
formo-benzoic 180
fluohydric - 60
fulminic - 82
gallic - 199
hippuric - 180
hydriodic - 60
hydrobromic 60

Page

Acid, hydrochloric 58
hydrocyanic 83
hydrofluoric 60
hypochlorous 43
hypophospho-
rous - 90
hyposulphurous 96
indigotic - 194
inosinic - 215
iodic - - 45
iodohydric - 60
itaconic - 198
kinic - - 199
lactic - - 170
lithofellic - 212
malic - - 198
manganic - 134
margaric - 201
meconic - 199
metagallic - 199
molybdic - 105
mucic - 168
muriatic - 58
nitric - 67
oleic - - 202
oleophosphoric 214
orsellic - 192
osmic - - 154
oxalic - - 78
palmitic - 204
paratartaric 198
phosphoric - 90
picric - - 194
pimelic - 203
prussic - 83
pyrocitric - 198
pyrophosphoric 91
racemic - 198
rocellic - 204
rubiacic - 192
saccharic - 170
sebacic - 202
selenic - 97
stearic - 201
suberic - 202
succinic - 202
sulphohydric 96
sulphuretted
hyposulphuric 96
sulphuric - 93
sulphurous - 93
tannic - - 198

Page

Acid, tartaric - 197
tartralic - 197
telluric - 98
thionuric - 85
titanic - 107
tungstic - 106
uric - - 85
valerianic - 178
vanadic - 105
Acid radicals - 47
Acids, tests for - 22
Aconitin - - 186
Acrolein - - 182
Acryle - - - 182
Air, atmospheric - 62
Albumen - - 167
Alcoates - - 173
Alcohol - - 171
Aldehyde - - 176
Algaroth powder - 102
Alkalimetry - - 110
Alkalies - - 108
Alkaloids - - 183
Alkaline earths - 117
Alizarin - - 191
Allantoin - - 85
Alloxan - - 85
Alloy, fusible - 146
Almonds, oil of - 179
Alum - - - 127
Alumina - - 126
Amalgams - - 147
Amides - - - 72
Ammonia - - 70
Amygdalin - - 179
Amyle series - 178
Animal chemistry - 207
Aniline - 180. 196
Animal charcoal - 73
Antimony - - 101
Archil - - - 192
Arrowroot - - 164
Arsenic and acids - 98
Atmosphere - - 62
Atomic theory - 39
weights - 2
Azote or nitrogen - 61

B

Balsams - - 182
Barium and barytes 117

	Page
Barometer	62
Bases, acid	47
alkaline	108
Beer	172
Benzoinamide	180
Benzoin	180
Benzoyle	179
Berberin	187
Bile	216
Bismuth	146
Bitters	188
Black lead	73
Bleaching	160
Bleaching powder	121
Blood	212
Blowpipe	14
Blue, Prussian	84
Bones, composition	208
Bone earth	123
Boron	86
Brain	214
Brandy	172
Brewing	171
Brezilin	193
Bromine	45
Brucin	187
Butter acids	203
C	
Cacodyle	177
Cadet, liquor of	178
Cadmium	141
Caffein	188
Calcium	119
Calculi	217
Calomel	147
Camphor	204
Caoutchouc	206
Caramel	169
Carbon	73
Carbonic acid	74
Casein	167
Cast iron	130
Catechu	199
Caustic soda	113
Cellulin	158
Cerasin	168
Cerebric acid	214
Cerium	128
Cerulin	194
Cetyle	182
Charcoal	73
Chemical nomenclature	39
Chemical terms, explanation	223
China clay	127
Chloral	176
Chlorimetry	122
Chlorine	41
Chlorisatin	195
Chloroform	162
Chlorophylle	190
Cholesterin	212
Cholic acid	211
Choleic acid	211
Choloidic acid	211
Chromium	103
Chyle	209
Coal	74, 160
Cobalt	135
Codein	185
Colouring matters	190
Columbium	106
Contagion	221
Copper	136
Corrosive sublimate	148
Cotton	161
Cotton, gun	69
Coumarin	205
Creasote	163
Creatin, Creatinine	215
Crystalline forms	6
Cudbear	192
Cumyle	182
Cyanogen	81
D	
Dextrin	159
Diabetic sugar	170
Diamond	73
Diastase	165
Digestion	209
Dimorphism	93
Distillation	57
Dry rot	160
Dyeing	161
E	
Earthenware	127
Earths, metals of	126
Elementary bodies	2
Emulsin	179
Equivalent weights	2
Erythric acid	192
Ethal	182
Ether	174
Ethyle	174
Excretions	205
Excrements	212
Exhalation	219
F	
Fats	200
Fermentation	171
Ferrocyanides	84
Fibrin	166
Flesh	215
Flour, analysis of	165
Fluorine	46
Food, law of, balance of	220
Formyle, terchloride of	162
G	
Gases, collection of	32
Gelatin	215
Glass	88, 112
Glucinum	128
Gluten	165
Glyceryle	182
Glycyrrhizin	170
Gold	150
Grape sugar	170
Graphite	73
Gum	168
Gum resins	206
Gypsum	123
H	
Hardness	4
Hæmatite	129
Hæmatosin	213
Hæmatoxylin	193
Humus	160
Hydrogen	47
Hyponitric acid	67
I	
Ice	55
Inulin	164
Indigo	194
Iodine	44
Iridium	153
Iron	129
Isatin	194
Isomerism	2
Isomorphism	2, 31
J	
Jeweller's gold	150
K	
Kelp	44
Kinic acid	199
Kreatin, see Creatin.	
L	
Leaves, function of	156
Lead	141
Lecanorin	192
Lichens	192
Lignin	158
Lime	119
Lithium	116
Litmus	196
Logwood	193
M	
Magnesia	123
Madder	191
Magnetic ore	129
Malt	171
Manganese	132

	Page
Manna	170
Manures	158, 218
Mercury	146
Mesityle	177
Metals	129
Methyle	162
Milk	216
Mortar	130
Mosaic gold	145
Muriatic acid	58
Murexide	86
Muscle	214
N	
Naptha	163
Napthaline	160, 163
Narcotin	185
Nerves	214
Nickel	134
Nitre	111
Nitric oxide	65
Nitrogen	61
Nitrous acid	66, 67
gas	65
oxide	64
Nomenclature	39
O	
Oils	200
Oily acids	201
Oil of grain	178
Opium	206
Orcein	192
Organic chemistry	155
Orpiment	101
Oxamide	78
Oxidation	38
Oxides	38
Oxygen	32
Ozone	32
P	
Palladium	153
Paper making	160
Pectin	168
Perspiration	219
Phloridzin	181
Phosphates	91
Phosphorus	89
Phosphuretted hydrogen	91
Picrotoxin	190
Plants, food of	155
Platinum	152
Platinocyanides	85
Plumbago	73
Pneumatic trough	34
Polychrome	191
Porcelain	127
Potassium	108
Potash	109
Potatoes, analysis of	166
Prussian blue	84
Prussic acid	83
Purple of Cassius	151
Pyroxylic spirit	162
Q	
Quercitron	196
Quinin	184
R	
Radicals, acid and basic	47, 108
Red colours	191
Resins	205
Respiration	219
Rhodium	153
Rubiacin	191
S	
Safflower	193
Salicin	181
Saliva	208
Saltpetre	111
Sanguification	212
Santalin	193
Sap of plants	168
Sarcosin	218
Selenium	97
Silica	86
Silver	138
Soaps	201
Soda	113
Specific gravities	7
Spirit of wood	162
proof	172
Squibs	112
Starches	164
Stearine	200
Steel	130
Stomach	209
Stoneware	129
Strontian	118
Strychnin	186
Sugars	162
Sulphur	92
Sulphocyanogen	84
Synaptase	179
Sulphuretted hydrogen	96
Symbols	2
T	
Tannin	198
Tantalum	106
Tapioca	164
Tartar, cream of	197
Taurin	211
Tellurium	97
Test paper	196
Thorium	128
Tin	144
Titanium	107
Tobacco	183
Tolu, balsam of	182
Tungsten	106
Turpentine, oil of	205
U	
Uranium	105
Urine	217
Urea	82
V	
Vanadium	104
Vegetation	156
Vinegar	176
Vitriol, oil of	93
W	
Water	54
Wax	205
Wheat flour	165
Wines	172
Whisky	172
Wood	159
Wool	161
Wort	171
Y	
Yeast or barm	171
Yttria	128
Z	
Zinc	140
Zirconia	128

THE END.

LONDON:
SPOTTISWOODE and SHAW,
New-street-Square.

NEW WORKS

IN MISCELLANEOUS AND GENERAL LITERATURE,

PUBLISHED BY

MESSRS. LONGMAN, BROWN, GREEN, AND LONGMANS,

PATERNOSTER ROW, LONDON.

CLASSIFIED INDEX.

AGRICULTURE & RURAL AFFAIRS.

	Pages
Bayldon on Valuing Rents, etc.	6
Crocker's Land Surveying	10
Davy's Agricultural Chemistry	10
Fresenius' " "	12
Johnson's Farmer's Encyclopædia	16
Loudon's Encyclopædia of Agriculture	19
" Self-Instruction for Farmers, etc.	18
" (Mrs.) Lady's Country Companion	18
Low's Breeds of the Domesticated Animals	20
" Elements of Agriculture	20
" On Landed Property	19
" On the Domesticated Animals	19
Parnell on Roads	24
Stewart on Transfer of Landed Property	29
Thomson on Fattening Cattle, etc.	30
Topham's Agricultural Chemistry	31

ARTS, MANUFACTURES, AND ARCHITECTURE.

Ball on the Manufacture of Tea	6
Brande's Dictionary of Science, etc.	7
Budge's Miner's Guide	7
Cartoons (The Prize)	8
Cresy's Encycl. of Civil Engineering	9
D'Agincourt's History of Art	10
Dresden Gallery	10
Eastlake on Oil Painting	11
Evans's Sugar Planter's Manual	11
Gwilt's Encyclopædia of Architecture	13
Haydon's Lectures on Painting & Design	13
Holland's Manufactures in Metal	17
Jameson's Sacred and Legendary Art	15
Loudon's Rural Architecture	19
Moseley's Engineering and Architecture	23
Parnell on Roads	24
Porter's Manufacture of Silk	17
" " Porcelain & Glass	17
Reid (Dr.) on Warming and Ventilating	25
Steam Engine (The), by the Artisan Club	5
Ure's Dictionary of Arts, etc.	31
Wood on Railroads	32

BIOGRAPHY.

Andersen's (H. C.) Autobiography	5
Bell's Lives of the British Poets	17
Dunham's Early Writers of Britain	17
" Lives of the British Dramatists	17
Forster's Statesmen of the Commonwealth	17
" Life of Jebb	17
Gleig's British Military Commanders	17
Grant (Mrs.) Memoir and Correspondence	12
Haydon's Autobiography and Journals	13
James's Life of the Black Prince	15
" Eminent Foreign Statesmen	17
Kindersley's De Bayard	16
Lál's (M.) Life of Dost Mohammed	28
Leslie's Life of Constable	18
Mackintosh's Life of Sir T. More	20
Maunder's Biographical Treasury	22
Roscoe's Lives of Eminent British Lawyers	17
Rowton's British Poetesses	26
Russell's Bedford Correspondence	6
Schopenhauer's Youthful Life	27
Shelley's Literary Men of Italy, etc.	17
" Eminent French Writers	17
Southey's Lives of the British Admirals	17
" Life of Wesley	29
Taylor's Loyola	30
Townsend's Twelve eminent Judges	31
Waterton's Autobiography and Essays	32

BOOKS OF GENERAL UTILITY.

Acton's (Eliza) Cookery Book	5
Black's Treatise on Brewing	6
Cabinet Lawyer (The)	8
Collegian's Guide	8
Donovan's Domestic Economy	17
Foster's Hand-book of Literature	12
Hints on Etiquette	13
Hudson's Executor's Guide	15
" On Making Wills	15
Hume's Account of Learned Societies, etc.	15
Loudon's Self Instruction	18
" (Mrs.) Amateur Gardener	18
Maunder's Treasury of Knowledge	22
" Scientific and Literary Treasury	22
" Treasury of History	22
" Biographical Treasury	22
" Natural History	22
Parkes's Domestic Duties	24
Pocket and the Stud	25
Pycroft's Course of English Reading	25
Reader's Time Tables	25
Rich's Companion to the Latin Dictionary	25
Riddle's Eng.-Lat. and Lat.-Eng. Dict.	26
Robinson's Art of Curing, Pickling, etc.	26
" Art of Making British Wines,	26
Rowton's Debater	26
Short Whist	27
Suitor's Instructor (The)	29
Thomson's Management of Sick Room	30
" Interest Tables	30
Webster's Encycl. of Domestic Economy	32
Zumpt's Latin Grammar	32

BOTANY AND GARDENING.

Abercrombie's Practical Gardener	5
" and Main's Gardener	5
Ball on the Cultivation of Tea	6
Calicott's Scripture Herbal	8
Conversations on Botany	9
Evans's Sugar Planter's Manual	11
Henslow's Botany	17
Hoare On the Grape Vine on Open Walls	14
" On the Roots of Vines	13
Hooker's British Flora	14
" Guide to Kew Gardens	14
Lindley's Theory of Horticulture	18
" Orchard and Kitchen Garden	18
" Introduction to Botany	18
" Synopsis of British Flora	18
Loudon's Hortus Britannicus	19

London: Printed by M. MASON, Ivy Lane, Paternoster Row.

	Pages
Loudon's Hortus Lignosus Londinensis	19
,, Encyclopædia of Trees & Shrubs	19
,, ,, Gardening	19
,, ,, Plants	19
,, Suburban Gardener	19
,, Self-Instruction for Gardeners	18
,, (Mr.) Amateur Gardener	18
Repton's Landscape Gardening, etc.	26
Rivers's Rose Amateur's Guide	26
Rogers's Vegetable Cultivator	26
Smith's Introduction to Botany	28
,, English Flora	28
,, Compendium of English Flora	28

CHRONOLOGY.

Blair's Chronological Tables	6
Bosanquet's Chronology of Ezra, etc.	7
Bunsen's Ancient Egypt	7
Nicolas's Chronology of History	17
Riddle's Ecclesiastical Chronology	26

COMMERCE AND MERCANTILE AFFAIRS.

Banfield and Weld's Statistics	6
Baylis's Arithmetic of Annuities	6
M'Culloch's Dictionary of Commerce	20
Reader's Time Tables	25
Steel's Shipmaster's Assistant	29
Symonds' Merchant Seamen's Laws	29
Thomson's Tables of Interest	30
Walford's Customs' Laws	31

GEOGRAPHY AND ATLASES.

Butler's Ancient and Modern Geography	8
,, Atlas of Modern Geography	8
,, ,, Ancient Geography	8
,, ,, General Geography	8
De Strzelecki's New South Wales	10
Erman's Travels through Siberia	11
Forster's Historical Geography of Arabia	11
Hall's Large General Atlas	13
M'Culloch's Geographical Dictionary	20
Mitchell's Australian Expedition	22
Murray's Encyclopædia of Geography	24
Parrot's Ascent of Mount Ararat	24
Schomburgk's Barbados, and Map	27

HISTORY AND CRITICISM.

Bell's History of Russia	17
Black Prince	6
Blair's Chron. and Historical Tables	6
Bloomfield's Translation of Thucydides	7
,, Edition of Thucydides	6
Bunsen's Ancient Egypt	7
Conybeare and Howson's St. Paul	9
Cooley's Maritime and Inland Discovery	17
Crowe's History of France	17
Coulton on Junius's Letters	9
De Simondi's Fall of the Roman Empire	17
,, Italian Republics	17
Dunham's History of Spain and Portugal	17
,, Europe in the Middle Ages	17
,, History of the German Empire	17
,, Denmark, Sweden, and Norway	17
,, History of Poland	17
Dunlop's History of Fiction	11
Eastlake's History of Oil Painting	11
Eccleston's English Antiquities	11
Foster's European Literature	12
Fergus's United States of America	12
Gibbon's Roman Empire	12
Grant (Mrs.) Memoir and Correspondence	12
Grattan's History of Netherlands	17
Grimblot's William III. and Louis XIV.	12
Halsted's Life of Richard III.	13
Harrison On the English Language	13
Haydon's Lectures on Painting and Design	13
Historical Charades	13
Historical Pictures of the Middle Ages	13
Jeffrey's (Lord) Contributions	16
Keightley's Outlines of History	17
Laing's Kings of Norway	16
Lempriere's Classical Dictionary	18
Macaulay's Essays	20
,, History of England	20
Mackintosh's History of England	17
,, Miscellaneous Works	20
M'Culloch's Dictionary, Historical, Geographical, and Statistical	20
Maunder's Treasury of History	22
Milner's Church History	22
Moore's History of Ireland	17
Mosheim's Ecclesiastical History	23
Nicolas's Chronology of History	17
Passages from Modern History	28
Ranke's History of the Reformation	25
Rich's Companion to the Latin Dictionary	25
Riddle's Latin Dictionaries	26
Rome, History of	17
Rowton's British Poetesses	26
Russell's Bedford Correspondence	6
Scott's History of Scotland	17
Sinnett's Byways of History	28
Southey's Doctor, etc.	29
Stebbing's History of the Christian Church	17
,, Church History	17
Switzerland, History of	17
Sydney Smith's Works	28
Taylor's Loyola	30
Thirlwall's History of Greece	30
Tooke's Histories of Prices	30
Turner's History of England	31
Zumpt's Latin Grammar	32

JUVENILE BOOKS.

Amy Herbert	5
Callcott's Home among Strangers	8
Gertrude	12
Gower's Scientific Phenomena	12
Historical Charades	13
Howitt's Boy's Country Book	14
,, Children's Year	14
Laneton Parsonage	8
Mackintosh's Life of Sir T. More	20
Marcet's Conversations—	
On Chemistry	21
On Natural Philosophy	21
On Political Economy	21
On Vegetable Physiology	21
On Land and Water	21
Maryat's Masterman Ready	21
,, Privateer's-Man	21
,, Settlers in Canada	21
,, Mission; or, Scenes in Africa	21
Passages from Modern History	28
Pycroft's Course of English Reading	25
Twelve Years Ago	31

MEDICINE.

Bull's Hints to Mothers	7
,, Management of Children	7
Copland's Dictionary of Medicine	9
Elliotson's Human Physiology	11
Holland's Medical Notes	14
Lane's Water Cure at Malvern	16
Latham On Diseases of the Heart	18
Pereira On Food and Diet	24
Sandby On Mesmerism	26
Thomson On Food	30

MISCELLANEOUS.

Blessington's Fugitive Fancies	6
Carey's Past, Present, and Future	8
Cartoons (The Prize)	8
Cocks's Bordeaux, its Wines, etc.	8
Collegian's Guide	8

	Pages
Colton's Lacon	9
Coulton On Authorship of Junius	9
De Jaenisch On Chess Openings	10
De la Gravière's Last Naval War	10
De Morgan On Probabilities	17
De Strzelecki's New South Wales	10
Dresden Gallery	10
Dunlop's History of Fiction	11
Field On Prison Discipline	11
Gardiner's Sights in Italy	12
Gower's Scientific Phenomena	12
Graham's English	12
Grant's Letters from the Mountains	12
Hobbes's (Thos.) complete Works	14
Hooker's Kew Guide	14
Howitt's Rural Life of England	15
,, Visits to Remarkable Places	14
,, Student Life of Germany	15
,, Rural and Social Life of Germany	15
,, Colonisation and Christianity	15
Hume's Account of Learned Societies	15
Jeffrey's (Lord) Contributions	16
Lane's Life at the Water Cure	16
Loudon's (Mrs.) Lady's Country Companion	18
Macaulay's Critical and Historical Essays	20
Mackintosh's (Sir J.) Miscellaneous Works	20
Maitland's Church in the Catacombs	21
Necker De Saussure's on Education	24
Plunkett On the Navy	25
Pycroft's Course of English Reading	25
Rich's Companion to the Latin Dictionary	25
Richter's Levana	26
Riddle's Latin Dictionaries	26
Roget's Economic Chess-board	26
Rowton's Debater	26
Sandy's Mesmerism	26
Sandford's Parochialia	26
Seaward's Narrative of his Shipwreck	27
Southey's Common-Place Book	29
,, Doctor, etc.	29
Suitor's Instructor (The)	29
Summerly's Sea and Railway	29
Sydney Smith's Works	28
Thomson on Food of Animals, etc.	30
Walker's Chess Studies	31
Willoughby's (Lady) Diary	32
Zumpt's Latin Grammar	32

NATURAL HISTORY IN GENERAL.

Catlow's Popular Conchology	8
Doubleday's Butterflies and Moths	10
Gray and Mitchell's Ornithology	12
,, ,, Accipitres	12
Kirby and Spence's Entomology	16
Lee's Taxidermy	18
,, Elements of Natural History	18
Maunder's Treasury of Natural History	22
Stephens' British Beetles	29
Swainson on the Study of Natural History	17
,, Animals	17
,, Quadrupeds	17
,, Birds	17
,, Animals in Menageries	17
,, Fish, Amphibia, and Reptiles	17
,, Insects	17
,, Malacology	17
,, Habits and Instincts	17
,, Taxidermy	17
Tarton's Shells of the British Islands	31
Waterton's Essays on Natural History	32
Westwood's Classification of Insects	32

NOVELS AND WORKS OF FICTION.

Callcott's Home among Strangers	8
Dunlop's History of Fiction	11
Hall's Midsummer Eve	13
Lady Willoughby's Diary	32
Madame De Malguet	21
Marryat's Masterman Ready	21
,, Privateer's-Man	21
,, Settlers in Canada	21
,, Mission; or, Scenes in Africa	21
Pericles, a Tale of Athens	24
Southey's Doctor, etc.	29
Twelve Years Ago	31

ONE VOLUME ENCYCLOPÆDIAS AND DICTIONARIES.

Blaine's, of Rural Sports	6
Brande's, of Science, Literature, and Art	7
Copland's, of Medicine	9
Cresy's, of Civil Engineering	9
Gwilt's, of Architecture	13
Johnson's Farmer	16
Loudon's, of Trees and Shrubs	19
,, of Gardening	19
,, of Agriculture	19
,, of Plants	19
,, of Rural Architecture	19
M'Culloch's Geographical Dictionary	20
,, Dictionary of Commerce	20
Murray's Encyclopædia of Geography	24
Ure's Arts, Manufactures, and Mines	31
Webster's Domestic Economy	32

POETRY AND THE DRAMA.

Aikin's (Dr.) British Poets	27
Chaleaor's Walter Gray	8
Collier's Roxburghe Ballads	9
Costello's Persian Rose Garden	9
Flowers and their Kindred Thoughts	11
Goldsmith's Poems, illustrated	12
Gray's Elegy, illuminated	12
Howitt's (Mary) Ballads	14
L. E. L.'s Poetical Works	16
Linwood's Anthologia Oxoniensis	18
Macaulay's Lays of Ancient Rome	20
Mackay's English Lakes	20
Montgomery's Poetical Works	23
Moore's Irish Melodies	23
,, Lalla Rookh	23
,, Poetical Works	23
Moral of Flowers	23
Poets' Pleasaunce	25
Rowton's British Poetesses	26
Shakspeare, by Bowdler	27
Sophocles, by Linwood	28
Southey's Poetical Works	29
,, British Poets	27
Spirit of the Woods	29
Thomson's Seasons, illustrated	30
,, with Notes, by Dr. A. T. Thomson	30

POLITICAL ECONOMY AND STATISTICS.

Banfield and Weld's Statistics	6
M'Culloch's Geographical, Statistical, and Historical Dictionary	20
M'Culloch's Dictionary of Commerce	20
,, Literature of Polit. Economy	21
,, On Succession to Property	21
,, On Taxation and Funding	21
,, Statistics of the British Empire	20
Marcet's Conversations on Polit. Economy	21
Symonds' Merchant Seamen's Law	29
Tooke's Histories of Prices	30
Twiss's (Dr.) View of Political Economy	31
,, Schleswig-Holstein Question	31

RELIGIOUS AND MORAL WORKS, ETC.

Amy Herbert, edited by Rev. W. Sewell	5
Barrett's Old Testament Criticisms	6

	Pages
Bloomfield's Greek Testament	7
,, College and School ditto	7
,, Lexicon to Greek Testament	7
Bunsen's Church of the Future	7
Burder's Oriental Customs	7
Burns's Christian Philosophy	8
,, Christian Fragments	8
Calicott's Scripture Herbal	8
Closing Scene	8
Conybeare and Howson's St. Paul	9
Cooper's Sermons	9
Coquerel's Christianity	9
Dale's Domestic Liturgy	10
Dibdin's Sunday Library	10
Discipline	10
Englishman's Hebrew Concordance	11
,, Greek Concordance	11
Forster's Historical Geography of Arabia	11
,, Life of Bishop Jebb	11
From Oxford to Rome	12
Gertrude, edited by the Rev. W. Sewell	12
Hook's (Dr.) Lectures on Passion Week	14
Horne's Introduction to the Scriptures	14
,, Compendium of ditto	14
Jameson's Sacred and Legendary Art	15
Jebb's Correspondence with Knox	15
,, Translation of the Psalms	16
Kip's Christmas in Rome	16
Knox's (Alexander) Remains	16
Laneton Parsonage	16
Letters to my Unknown Friends	18
Maitland's Church in the Catacombs	21
Margaret Percival	21
Milner's Church History	22
Miracles of Our Saviour	22
Moore on the Power of the Soul	23
,, on the Use of the Body	23
,, on Man and his Motives	23
Mosheim's Ecclesiastical History	23
Parables of Our Lord	24
Parkes's Domestic Duties	24
Pitman's Sermons on the Psalms	25
Ranke's Reformation	25
Renaud's Matutina	25
Rest in the Church	25
Riddle's Letters from a Godfather	26
Sandford On Female Improvement	27
,, On Woman	27
,, 's Parochialia	26
Sermon on the Mount (The)	27
Shunammite (The Good)	27
Sinclair's Journey of Life	28
,, Business of Life	27
Sketches (The)	28
Smith's (G.) Perilous Times	28
,, Religion of Ancient Britain	28
,, Sacred Annals	28
,, (J.) St. Paul's Shipwreck	28
Soames's Latin Church	28
Southey's Life of Wesley	29
Stebbing's Christian Church	17
,, Reformation	17
Stephen's Church of Scotland	29
Sydney Smith's Sermons	28
Tate's History of St. Paul	29
Tayler's (Rev. C. B.) Margaret	30
,, ,, Lady Mary	30
Taylor's (Jeremy) Works	30
,, (Isaac) Loyola	30
Tomline's Introduction to the Bible	30
Turner's Sacred History	31
Twelve Years Ago	31
Walker's Elementa Liturgica	31
Wardlaw On Socinian Controversy	31
Wilberforce's View of Christianity	32
Willoughby's (Lady) Diary	32
Wilson's Lands of the Bible	32
Wisdom of Johnson's Rambler, etc.	16
Woodward's Sermons and Essays	32
,, Sequel to Shunammite	32

RURAL SPORTS.

	Pages
Blaine's Dictionary of Sports	6
Ephemera on Angling	11
Hawbuck Grange	13
Hawker's Instructions to Sportsmen	13
Jones's Norway Salmon Fisher	16
Loudon's (Mrs.) Lady's Country Companion	18
Pocket and the Stud	25
Stable Talk and Table Talk	29

THE SCIENCES IN GENERAL, AND MATHEMATICS.

Baker's Railway Engineering	5
Bakewell's Introduction to Geology	5
Brande's Dictionary of Science, etc.	7
Brewster's Optics	17
Conversations on Mineralogy	9
De la Beche on the Geology of Cornwall, etc.	10
Donovan's Chemistry	17
Farey on the Steam Engine	11
Fosbroke on the Arts of the Ancients	17
Gower's Scientific Phenomena	12
Herschel's Natural Philosophy	17
,, Astronomy	17
Holland's Manufactures in Metal	17
Humboldt's Cosmos	15
Hunt's Researches on Light	15
Kater and Lardner's Mechanics	17
Lardner's Cabinet Cyclopædia	17
,, Hydrostatics and Pneumatics	17
,, and Walker's Electricity	17
,, Arithmetic	17
,, Geometry	17
,, Treatise on Heat	17
Low's Chemistry	19
Marcet's Conversations on the Sciences	21
Matteucci On Physical Phenomena	21
Memoirs of the Geological Survey	22
Moseley's Practical Mechanics	23
,, Engineering and Architecture	23
Owen's Lectures On Comparative Anatomy	24
Peschel's Physics	24
Phillips's Palæozoic Fossils of Cornwall, etc.	24
,, Mineralogy, by Prof. Miller	25
,, Treatise on Geology	17
Portlock's Geology of Londonderry	25
Powell's Natural Philosophy	17
Ritchie (Robert) on Railways	26
Topham's Agricultural Chemistry	31

TRAVELS.

Allan's Mediterranean	5
Borrer's Campaign in Algeria	7
Costello's (Miss) North Wales	9
Coulter's California, etc.	9
,, Pacific	9
De Strzelecki's New South Wales	10
Dunlop's Central America	10
Erman's Travels through Siberia	11
Gardiner's Sights in Italy	12
Harris's Highlands of Æthiopia	13
Jones's Norway Guide	16
Kip's Holydays in Rome	16
Laing's Tour in Sweden	16
Mackay's English Lakes	20
Marryat's Borneo	21
Mitchell's Expedition into Australia	22
Parrot's Ascent of Mount Ararat	24
Schomburgk's Barbados	27
Schopenhauer's Pictures of Travel	27
Seaward's Narrative of his Shipwreck	27
Tischendorff's Travels in the East	30
Von Orlich's Travels in India	31
Wilson's Travels in the Holy Land	32

VETERINARY MEDICINE

Miles On the Horse's Foot	22
Pocket and the Stud	25
Stable Talk and Table Talk	29
Thomson on Fattening Cattle	30
Winter On the Horse	32

NEW WORKS AND NEW EDITIONS

PUBLISHED BY

MESSRS. LONGMAN, BROWN, GREEN, AND LONGMANS.

ACTON (MISS).—MODERN COOKERY,
In all its Branches, reduced to a System of Easy Practice. For the use of Private Families. In a Series of Practical Receipts, all of which have been strictly tested, and are given with the most minute exactness. By Eliza Acton. New Edition, to which are added, Directions for Carving. Foolscap 8vo. with Plates and Woodcuts, *7s. 6d.* cloth.

"The whole of Miss Acton's recipes' with a few trifling exceptions, which are scrupulously specified, are confined to such as may be perfectly depended on, from having been proved beneath our own roof, and under our own personal inspection.' We add, moreover, that the recipes are all reasonable, and never in any instance extravagant. They do not bid us sacrifice ten pounds of excellent meat, that we may get a couple of quarts of gravy from it; nor do they deal with butter and eggs as if they cost nothing. Miss Acton's book is a good book in every way; there is right-mindedness in every page of it, as well as thorough knowledge and experience of the subjects she handles."—Medical Gazette.

ABERCROMBIE.—ABERCROMBIE'S PRACTICAL GARDENER, AND IMPROVED SYSTEM OF MODERN HORTICULTURE, alphabetically arranged. New Edition, with an Introductory Treatise on Vegetable Physiology; and Plates by W. Salisbury. 12mo. *6s.* boards.

ABERCROMBIE AND MAIN.—THE PRACTICAL GARDENER'S COMPANION; Or, Horticultural Calendar: to which is added, the Garden-Seed and Plant Estimate. Edited, from a MS. of J. Abercrombie, by J. Main. New Edition. 32mo. *3s. 6d.* sewed.

ALLAN (J. H.)—A PICTORIAL TOUR IN THE MEDITERRANEAN;
Comprising Malta, Dalmatia, Turkey, Asia Minor, Grecian Archipelago, Egypt, Nubia, Greece, Sicily, Italy, and Spain. J. H. Allan. New Edition. Imperial 4to. with upwards of 40 lithographed Drawings, and 70 Wood Engravings, *3l. 3s.* cloth.

AMY HERBERT.
By a Lady. Edited by the Rev. William Sewell, B.D. of Exeter College, Oxford. New Edition. 2 vols. foolscap 8vo. *9s.* cloth.

ANDERSEN.—THE TRUE STORY OF MY LIFE;
A Sketch. By Hans Christian Andersen, author of "The Shoes of Fortune," "The Nightingale," "O. T.," "Only a Fiddler," "The Improvisatore," etc. Translated by Mary Howitt. Fcp. 8vo. *5s.* cloth.

ARTISAN CLUB (THE).—A TREATISE ON THE STEAM-ENGINE.
In its application to Mines, Mills, Steam Navigation, and Railways. By the Artisan Club. Edited by John Bourne, C.E. New Edition. 4to. with 30 Steel Plates, etc., and about 350 Wood Engravings, *27s.* cloth.

BAKER.—RAILWAY ENGINEERING;
Containing the most approved Methods of laying out Railway Curves, and of setting out the Cuttings, Embankments, and Tunnels of Railways: with a General and two Auxiliary Tables, for the Calculation of Earthworks of Railways, Canals, etc. Also, the Investigation of the Formula for the Superelevation of the exterior Rail in Curves. By T. Baker, Surveyor and Civil Engineer. 8vo. *5s.* cloth.

BAKEWELL.—AN INTRODUCTION TO GEOLOGY.
Intended to convey Practical Knowledge of the Science, and comprising the most important recent Discoveries. By Robert Bakewell. Fifth Edition, 8vo. with Plates and Woodcuts, *21s.* cloth.

BALL.—AN ACCOUNT OF THE CULTIVATION AND MANUFACTURE OF TEA IN CHINA: derived from Personal Observation during an Official Residence in that Country of upwards of Twenty Years; and illustrated by the best Authorities, Chinese as well as European. With some Remarks on the Experiments now making for the Introduction of the Culture of the Tea Tree in other parts of the World. By S. Ball, Esq. late Inspector of Teas to the East India Company in China. 8vo. with Plates and Woodcuts, 14*s.* cloth.

BANFIELD AND WELD.—THE STATISTICAL COMPANION;
Exhibiting the most interesting Facts in Moral and Intellectual, Vital, Economical, and Political Statistics, at home and abroad. Compiled from Official and other authentic Sources, by T. C. Banfield, Statistical Clerk to the Council of Education; and C. R. Weld, Assistant Secretary to the Royal Society. Foolscap 8vo. 5*s.* cloth.

BARRETT.—A SYNOPSIS OF CRITICISMS
Upon those Passages of the Old Testament in which Modern Commentators have differed from the Authorized Version: together with an Explanation of various Difficulties in the Hebrew and English Texts. By the Rev. Richard A. F. Barrett, M.A. Fellow of King's College, Cambridge. Vols. I. and II. 8vo. 28*s.* each cloth; or in 4 Half-vols. 14*s.* each. Also, Half-vol. V. 14*s.*

BAYLDON.—THE ART OF VALUING RENTS AND TILLAGES,
And the Tenant's Right of Entering and Quitting Farms, explained by several Specimens of Valuations; and Remarks on the Cultivation pursued on Soils in different Situations. Adapted to the Use of Landlords, Land-Agents, Appraisers, Farmers, and Tenants. By J. S. Bayldon. New Edition, corrected and revised by John Donaldson. 8vo. 10*s.* 6*d.* cloth.

BAYLIS.—THE ARITHMETIC OF ANNUITIES AND LIFE ASSURANCE;
Or, Compound Interest simplified. Explaining the Value of Annuities, certain or contingent on One or Two Lives, and the Values of Assurances in Single and Annual Payments; and comprehending Leases, Pensions, Freeholds, and Reversionary Sums, etc. By Edward Baylis. 8vo. 5*s.* cloth.

BEDFORD CORRESPONDENCE.—CORRESPONDENCE OF JOHN, FOURTH DUKE OF BEDFORD, selected from the Originals at Woburn Abbey, (1742-70). With Introductions by Lord John Russell. 3 vols. 8vo. 42*s.* cloth.

*** *Vol. I.* (1742-48), 18*s.*; *Vol. II.* (1749-60), 17*s.*; *Vol. III.* (1761-70), 15*s.*

BLACK PRINCE.—A RECORD OF THE BLACK PRINCE;
Being some of the most striking Passages of his Life—in *the Words* of his Chroniclers, selected more especially from the records of his contemporary Froissart, in the quaint and spirited translation made by Lord Berners for King Henry VIII. Post 8vo., printed in black letter, embellished with Illuminated Borders and Miniatures, and bound in imitative carving. [*In the press.*

BLACK.—A PRACTICAL TREATISE ON BREWING.
Based on Chemical and Economical Principles: with Formulæ for Public Brewers, and Instructions for Private Families. By William Black. Third Edition, revised and corrected, with considerable Additions. 8vo. 10*s.* 6*d.* cloth.—Also,

SUPPLEMENT, of REMARKS on BAVARIAN BEER, etc. 8vo. 2*s.* 6*d.* sewed.

BLAINE.—AN ENCYCLOPÆDIA OF RURAL SPORTS;
Or, a complete Account, Historical, Practical, and Descriptive, of Hunting, Shooting, Fishing, Racing, and other Field Sports and Athletic Amusements of the present day. By Delabere P. Blaine, Esq., author of "Canine Pathology," etc. With nearly 600 Engravings on Wood, by R. Branston, from Drawings by Alken, T. Landseer, Dickes, etc. 8vo. 50*s.* cloth.

BLAIR'S CHRONOLOGICAL AND HISTORICAL TABLES,
From the Creation to the present Time: with Additions and Corrections from the most authentic Writers; including the Computation of St. Paul, as connecting the Period from the Exode to the Temple. Under the revision of Sir Henry Ellis, K.H., Principal Librarian of the British Museum. Imperial 8vo. 31*s.* 6*d.* half-bound morocco.

BLESSINGTON.—FUGITIVE FANCIES.
By the Countess of Blessington. Fcap. 8vo. [*In the press.*

BLOOMFIELD.—THE HISTORY OF THE PELOPONNESIAN WAR.
By Thucydides. A New Recension of the Text, with a carefully amended Punctuation; and copious Notes, Critical, Philological, and Explanatory, almost entirely original, but partly selected and arranged from the best Expositors: accompanied with full Indexes. Illustrated by Maps and Plans. By the Rev. S. T. Bloomfield, D.D. F.S.A. 2 vols. 8vo. 38*s.* cloth.

BLOOMFIELD.—THE HISTORY OF THE PELOPONNESIAN WAR.
By Thucydides. Translated into English, and accompanied with very copious Notes, Philological and Explanatory, Historical and Geographical. By the Rev. S. T. Bloomfield, D.D. F.S.A. 3 vols. 8vo. with Maps and Plates, 2*l.* 5*s.* boards.

BLOOMFIELD.—THE GREEK TESTAMENT:
With copious English Notes, Critical, Philological, and Explanatory. Formed for the use of advanced Students of Divinity and Candidates for Holy Orders. By the Rev. S. T. Bloomfield, D.D. F.S.A. New Edition. 2 vols. 8vo. with a Map of Palestine, 40*s.* cloth.

BLOOMFIELD.—THE GREEK TESTAMENT FOR COLLEGES AND SCHOOLS; with shorter English Notes, Critical, Philological, and Explanatory. By the Rev. S. T. Bloomfield, D.D. New Edition, enlarged, with a New Map and an Index. Foolscap 8vo. 10*s.* 6*d.* cloth.

BLOOMFIELD.—GREEK AND ENGLISH LEXICON TO THE NEW TESTAMENT: especially adapted to the use of Colleges, and the Higher Classes in Public Schools; but also intended as a convenient Manual for Biblical Students in general. By Dr. Bloomfield. New Edition, improved. Foolscap 8vo. 10*s.* 6*d.* cloth.

BORRER.—NARRATIVE OF A CAMPAIGN WITH A FRENCH COLUMN,
under Maréchal Bugeaud, directed against the Kabiles of Algeria: together with an Account of the Adventures of M. Suchet in search of the Camp of the Emir Abd-el-Kader. By Dawson Borrer, F.R.G.S. Membre Correspondant de la Société Orientale à Paris, author of "A Journey from Naples to Jerusalem." Post 8vo. [*Nearly ready.*

BOSANQUET.—CHRONOLOGY OF THE TIMES OF DANIEL, EZRA,
AND NEHEMIAH, considered with the view of correcting an Error of Thirty-three Years in the received Chronology between the Capture of Jerusalem by Nebuchadnezzar and the Birth of Christ. Leading to an Explanation of the Prophecy of the Seventy Weeks, the Recovery of the lost Era of the Jubilee, and the Rectification of several important Dates in Scripture Chronology. By J. Whatman Bosanquet, Esq. Part I. 8vo. 8*s.* 6*d.* cloth.

BRANDE.—A DICTIONARY OF SCIENCE, LITERATURE, AND ART;
Comprising the History, Description, and Scientific Principles of every Branch of Human Knowledge; with the Derivation and Definition of all the Terms in general use. Edited by W. T. Brande, F.R.S.L. and E.; assisted by Dr. J. Cauvin. 8vo. with Woodcuts, 3*l.* cloth.

BUDGE (J.)—THE PRACTICAL MINER'S GUIDE.
Comprising a Set of Trigonometrical Tables adapted to all the purposes of Oblique or Diagonal, Vertical, Horizontal, and Traverse Dialling; with their application to the Dial, Exercise of Drifts, Lodes, Slides, Levelling, Inaccessible Distances, Heights, etc. By J. Budge. New Edition, enlarged. 8vo. with Portrait, 12*s.* cloth.

BULL.—HINTS TO MOTHERS,
For the Management of Health during the Period of Pregnancy and in the Lying-in Room; with an Exposure of Popular Errors in connexion with those subjects. By Thomas Bull, M.D. New Edition, revised and considerably enlarged. Foolscap 8vo. 7*s.* cloth.

BULL.—THE MATERNAL MANAGEMENT OF CHILDREN,
in HEALTH and DISEASE. By Thomas Bull, M.D. Physician Accoucheur to the Finsbury Midwifery Institution, etc. New Edition, revised and enlarged. Foolscap 8vo. 5*s.* cloth.

BUNSEN.—THE CONSTITUTION OF THE CHURCH OF THE FUTURE.
A practical Explanation of the Correspondence with the Right Hon. William Gladstone, on the German Church, Episcopacy, and Jerusalem. With a Preface, Notes, and the complete Correspondence. By the Chevalier C. C. J. Bunsen, Ph.D., D.C.L. Translated under the superintendence of and with additions by the Author. Post 8vo. 9*s.* 6*d.* cloth.

BUNSEN.—EGYPT'S PLACE IN UNIVERSAL HISTORY:
An Historical Investigation, in Five Books. By C. C. J. Bunsen, D. Ph. and D.C.L. Translated from the German, by C. H. Cottrell, Esq. M.A. Vol. I. containing the First Book, or Sources and Primeval Facts of Egyptian History with an Egyptian Grammar and Dictionary, and a complete List of Hieroglyphical Signs: an Appendix of Authorities, embracing the complete Text of Manetho and Eratosthenes, Ægyptiaca from Pliny, Strabo, etc.; and Plates representing the Egyptian Divinities. 8vo. with numerous Illustrations, 28*s.* cloth.

BURDER.—ORIENTAL CUSTOMS,
Applied to the Illustration of the Sacred Scriptures. By Dr. Samuel Burder. New Edition, with Additions. Foolscap 8vo. 8*s.* 6*d.* cloth.

BURNS.—THE PRINCIPLES OF CHRISTIAN PHILOSOPHY;
Containing the Doctrines, Duties, Admonitions, and Consolations of the Christian Religion. By John Burns, M.D. F.R.S. 6th Edition. Foolscap 8vo. 6s. 6d. cloth.

BURNS.—CHRISTIAN FRAGMENTS;
Or, Remarks on the Nature, Precepts, and Comforts of Religion. By John Burns, M.D. F.R.S. Foolscap 8vo. 5s. cloth.

BUTLER.—A SKETCH OF MODERN AND ANCIENT GEOGRAPHY.
By Samuel Butler, D.D., late Lord Bishop of Lichfield and Coventry; and formerly Head Master of Shrewsbury School. New Edition, revised by the Author's Son. 8vo. 9s. boards.

BUTLER.—AN ATLAS OF MODERN GEOGRAPHY.
Consisting of Twenty-three coloured Maps, from a New Set of Plates; with an Index of all the Names of Places, referring to the Latitudes and Longitudes. By the late Dr. Butler, Bishop of Lichfield. New Edition, corrected. 8vo. 12s. half-bound.

BUTLER.—AN ATLAS OF ANCIENT GEOGRAPHY.
Consisting of Twenty-three coloured Maps: with an Index of all the Names of Places, referring to the Latitudes and Longitudes. By the late Dr. Butler, Bishop of Lichfield. New Edition, corrected. 8vo. 12s. half-bound.

BUTLER.—A GENERAL ATLAS OF MODERN AND ANCIENT GEOGRAPHY.
Consisting of Forty-five coloured Maps, and copious Indices referring to the Latitudes and Longitudes. By the late Dr. Butler, Bishop of Lichfield. New Edition, from an entirely new and corrected set of Plates. 4to. 24s. half-bound.

CABINET LAWYER (THE).
A Popular Digest of the Laws of England, Civil and Criminal; with a Dictionary of Law Terms, Maxims, Statutes, and Judicial Antiquities; Correct Tables of Assessed Taxes, Stamp Duties, Excise Licences, and Post-Horse Duties; Post-Office Regulations, and Prison Discipline. Fourteenth Edition, enlarged, and corrected throughout, with the Legal Decisions and Statutes to Michaelmas Term, 10 and 11 Victoria. Fcap. 8vo. 10s. 6d. cloth.

CALLCOTT.—HOME AMONG STRANGERS:
A Tale. By Maria Hutchins Callcott. 2 vols. fcap. 8vo. 9s. cloth.

CALLCOTT.—A SCRIPTURE HERBAL:
With upwards of 120 Wood Engravings. By Lady Callcott. Square crown 8vo. 1l. 5s. cloth.

CAREY.—THE PAST, THE PRESENT, AND THE FUTURE.
By H. C. Carey, author of "The Principles of Political Economy," etc. 8vo. 10s. 6d. cloth.

CARTOONS.—THE PRIZE CARTOONS EXHIBITED IN WESTMINSTER-HALL, Published under the Sanction and Patronage of Her Majesty's Commissioners on the Fine Arts. Eleven large folio Engravings, in a neat Portfolio, 5l. 5s.; Proofs before letters, 8l. 8s.

CATLOW.—POPULAR CONCHOLOGY;
Or, the Shell Cabinet arranged: being an Introduction to the modern System of Conchology; with a sketch of the Natural History of the Animals, an account of the Formation of the Shells, and a complete Descriptive List of the Families and Genera. By Agnes Catlow. Foolscap 8vo. with 312 Woodcuts, 10s. 6d. cloth.

CHALENOR.—WALTER GRAY,
A Ballad, and other Poems. By Mary Chalenor. 2d Edition, with Additions, including the Author's Poetical Remains. Fcap. 8vo. 6s. cloth.

THE CLOSING SCENE;
Or, Christianity and Infidelity contrasted in the Last Hours of Remarkable Persons. By the Author of "The Bishop's Daughter," "Self-Sacrifice," "The Life-Book of a Labourer," etc. Fcap. 8vo. 6s. cloth.

COCKS (C.)—BORDEAUX, ITS WINES, AND THE CLARET COUNTRY.
By C. Cocks, B.L., Professor of the Living Languages in the Royal Colleges of France; Translator of the Works of Michelet, Mignet, and Quinet. Post 8vo. 8s. 6d. cloth.

COLLEGIAN'S GUIDE (THE);
Or, Recollections of College Days; setting forth the Advantages and Temptations of a University Education. By the Rev. James Pycroft, M.A. Post 8vo. 10s. 6d. cloth.

COLLIER (J. PAYNE.)—A BOOK OF ROXBURGHE BALLADS.
Edited by John Payne Collier, Esq. Fcap. 4to. with Woodcuts, 21*s.* boards; morocco, 38*s.*

COLTON—LACON; OR, MANY THINGS IN FEW WORDS.
By the Rev. C. C. Colton. New Edition. 8vo. 12*s.* cloth.

CONVERSATIONS ON BOTANY.
New Edition, improved. Foolscap 8vo. with 22 Plates, 7*s.* 6*d.* cloth; with coloured Plates, 12*s.*

CONVERSATIONS ON MINERALOGY.
With Plates, engraved by Mr. and Mrs. Lowry, from Original Drawings. Third Edition, enlarged. 2 vols. foolscap 8vo. 14*s.* cloth.

CONYBEARE AND HOWSON.—THE LIFE AND LETTERS OF ST. PAUL;
comprising a complete Biography of the Apostle, and a Paraphrastic Translation of his Epistles inserted in Chronological order. Edited by the Rev. W. J. Conybeare, M.A. late Fellow of Trinity College, Cambridge; and the Rev. J. S. Howson, M.A. Principal of the Collegiate Institution, Liverpool. 4to. richly illustrated by Maps, Views, Engravings of Coins, etc. *[In the press.*

COOPER (THE REV. E.)—PRACTICAL AND FAMILIAR SERMONS,
Designed for Parochial and Domestic Instruction. By the Rev. Edward Cooper. New Editions. 7 vols. 12mo. 1*l.* 18*s.* boards.

COOPER (THE REV. E.)—SERMONS,
Chiefly designed to elucidate some of the leading Doctrines of the Gospel. By the Rev. Edward Cooper. New Edition. 2 vols. 12mo. 10*s.* boards.

COPLAND.—A DICTIONARY OF PRACTICAL MEDICINE;
Comprising General Pathology, the Nature and Treatment of Diseases, Morbid Structures, and the Disorders especially incidental to Climates, to Sex, and to the different Epochs of Life, with numerous approved Formulæ of the Medicines recommended. By James Copland, M.D., etc. etc. Vols. I. and II., 8vo. 3*l.* cloth; and Parts X. to XIII. 4*s.* 6*d.* each.

COQUEREL.—CHRISTIANITY;
Its perfect adaptation to the Mental, Moral, and Spiritual Nature of Man. By Athanase Coquerel, one of the Pastors of the French Protestant Church in Paris. Translated by the Rev. D. Davison, M.A. With an Introductory Notice of the State of the Protestant Church of France, written by the Author for the English Edition. Post 8vo. 12*s.* cloth.

COSTELLO (MISS).—THE ROSE GARDEN OF PERSIA.
A Series of Translations from the Persian Poets. By Louisa Stuart Costello, author of "Specimens of the Early Poetry of France," etc. Long 8vo. with 12 Illuminated Titles, and Borders printed in Colours, 18*s.* boards; or 31*s.* 6*d.* morocco.

COSTELLO (MISS)—FALLS, LAKES, AND MOUNTAINS OF NORTH WALES; being a Pictorial Tour through the most interesting parts of the Country. By Louisa Stuart Costello, author of "The Rose Garden of Persia," etc. Profusely illustrated with Views, from Original Sketches by D. H. M'Kewan, engraved on wood, and lithographed, by T. and E. Gilks. Square 8vo. with Map, 14*s.* cloth.

COULTER.—ADVENTURES ON THE WESTERN COAST OF SOUTH AMERICA AND IN THE INTERIOR OF CALIFORNIA. Including a Narrative of Incidents at the Kingsmill Islands, New Ireland, New Britain, New Guinea, and other Islands in the Pacific Ocean. With an Account of the Natural Productions, and the Manners and Customs, in Peace and War, of the various Savage Tribes visited. By John Coulter, M.D. author of "Adventures in the Pacific." 2 vols. post 8vo. 16*s.* cloth.

COULTER.—ADVENTURES IN THE PACIFIC;
With Observations on the Natural Productions, Manners and Customs of the Natives of the various Islands; Remarks on the Missionaries, British and other Residents, etc. By John Coulter, M.D. Post 8vo. 7*s.* 6*d.* cloth.

COULTON.—AN INQUIRY INTO THE AUTHORSHIP OF THE LETTERS OF JUNIUS. By David Trevena Coulton. 4to. *[In November.*

CRESY (E.)—AN ENCYCLOPÆDIA OF CIVIL ENGINEERING, HISTORICAL, THEORETICAL, and PRACTICAL. By Edward Cresy, F.S.A. C.E. Illustrated by upwards of Three Thousand Engravings on Wood, explanatory of the Principles, Machinery, and Constructions which come under the Direction of the Civil Engineer. One large Volume 8vo. upwards of 1,600 pages, 3*l.* 13*s.* 6*d.* cloth.

CROCKER'S ELEMENTS OF LAND SURVEYING.
Fifth Edition, corrected throughout, and considerably improved and modernised, by T. G. Bunt, Land Surveyor, Bristol. To which are added, TABLES OF SIX-FIGURE LOGARITHMS, etc., superintended by Richard Farley, of the Nautical Almanac Establishment. Post 8vo. 12s. cloth.

D'AGINCOURT.—THE HISTORY OF ART,
By its Monuments, from its Decline in the Fourth Century to its Restoration in the Sixteenth. Translated from the French of Seroux D'Agincourt, by Owen Jones, architect. With 3,335 Subjects, engraved on 328 Plates. Vol. I. Architecture, 73 plates; vol. II. Sculpture, 51 plates; vol. III. Painting, 204 plates. 3 vols. royal folio, 5*l.* 5*s.* sewed.

DALE (THE REV. THOMAS).—THE DOMESTIC LITURGY AND
FAMILY CHAPLAIN, in Two Parts: the First Part being Church Services adapted for Domestic Use, with Prayers for every Day of the Week, selected exclusively from the Book of Common Prayer. Part II. comprising an appropriate Sermon for every Sunday in the Year. By the Rev. Thomas Dale, M.A. Vicar of St. Pancras. Post 4to. 21*s.* cloth: or, bound by Hayday, 31*s.* 6*d.* calf lettered; 50*s.* morocco.

DAVY (SIR HUMPHRY).—ELEMENTS OF AGRICULTURAL CHEMISTRY
in a Course of Lectures. By Sir Humphry Davy. With Notes by Dr. John Davy. New Edition. 8vo. with 10 Plates, 15*s.* cloth.

DE JAENISCH AND WALKER.—DE JAENISCH'S CHESS PRECEPTOR:
A New Analysis of the Openings of Games. By C. F. De Jaenisch, of St. Petersburgh. Translated from the French, with copious Notes, by G. Walker, author of "Chess Studies," and various other Works on the Game of Chess. 8vo. 15*s.* cloth.

DE LA BECHE.—REPORT ON THE GEOLOGY OF CORNWALL, DEVON,
AND WEST SOMERSET. By Henry T. De la Beche, F.R.S. etc., Director of the Ordnance Geological Survey. Published by Order of the Lords Commissioners of H. M. Treasury. 8vo. with Maps, Woodcuts, and 12 large Plates, 14*s.* cloth.

DE LA GRAVIERE.—SKETCHES OF THE LAST NAVAL WAR.
Translated from the French of Captain E. Jurien de la Gravière, with an Introduction, and Explanatory Notes. By the Hon. Captain Plunkett, R. N., author of "The Past and Future of the British Navy." 2 vols. post 8vo. with Plans, 18*s.* cloth.

DE STRZELECKI (P. E.)—PHYSICAL DESCRIPTION OF NEW SOUTH
WALES AND VAN DIEMAN'S LAND. Accompanied by a Geological Map, Sections, and Diagrams, and Figures of the Organic Remains. By P. E. De Strzelecki. 8vo. with coloured Map and numerous Plates, 24*s.* cloth.

DIBDIN (THE REV. T. F.)—THE SUNDAY LIBRARY:
Containing nearly One hundred Sermons by eminent Divines. With Notes, etc. by the Rev. T. F. Dibdin, D.D. 6 vols. foolscap 8vo. with 6 Portraits, 30*s.* cloth; neatly half-bound in morocco, with gilt edges, 2*l.* 12*s.* 6*d.*

DISCIPLINE.
By the Author of "Letters to my Unknown Friends," "Twelve Years Ago," and "Some Passages from Modern History." 18mo. 2*s.* cloth.

DOUBLEDAY AND HEWITSON'S BUTTERFLIES.—THE GENERA OF
DIURNAL LEPIDOPTERA; comprising their Generic Characters—a Notice of the Habits and Transformations—and a Catalogue of the Species of each Genus. By Edward Doubleday, Esq. F.L.S. etc., Assistant in the Zoological Department of the British Museum. Imperial 4to. uniform with Gray and Mitchell's Ornithology; illustrated with 75 coloured Plates, by W. C. Hewitson, Esq. Author of "British Oology."

*** *Publishing in Monthly Parts, 5s. each; each Part consisting of two coloured Plates, with accompanying Letter-press. To be completed in not exceeding 40 Parts, 22 of which are now ready.*

DRESDEN GALLERY.—THE MOST CELEBRATED PICTURES OF THE
ROYAL GALLERY at DRESDEN, drawn on Stone, from the Originals, by Franz Haufstaengel: with Descriptive and Biographical Notices, in French and German. Nos. I. to LII., imperial folio, each containing 3 Plates with accompanying Letter-press, price 20*s.* to Subscribers; to Non-subscribers, 30*s.* Single Plates, 12*s.* each.

*** *To be completed in 8 more numbers, price 20s. each, to Subscribers; Nos. LI. to LX. containing each 4 Plates and Letterpress.*

DUNLOP.—TRAVELS IN CENTRAL AMERICA.
With a Journal of nearly Three Years' Residence in the Country. To which are added, a Sketch of the History of the Republic, and an Account of its Climate, Productions, Commerce, etc. By Robert Glasgow Dunlop, Esq. Post 8vo. with Map, 10*s.* 6*d.* cloth.

DUNLOP (JOHN).—THE HISTORY OF FICTION:
Being a Critical Account of the most celebrated Prose Works of Fiction, from the earliest Greek Romances to the Novels of the Present Age. By John Dunlop. New Edition, complete in One Volume. Medium 8vo. 15*s.* cloth.

EASTLAKE.—MATERIALS FOR A HISTORY OF OIL PAINTING.
By Charles Lock Eastlake, Esq. R.A. F.R.S. F.S.A. Secretary to the Royal Commission for Promoting the Fine Arts in connexion with the rebuilding of the Houses of Parliament, etc. 8vo. 16*s.* cloth.

ECCLESTON (JAMES).—AN INTRODUCTION TO ENGLISH ANTIQUITIES,
Intended as a Companion to the History of England. By James Eccleston, B.A. Head Master of Sutton Coldfield Grammar School. 8vo. with numerous Engravings on Wood, 21*s.* cloth.

ELLIOTSON.—HUMAN PHYSIOLOGY:
With which is incorporated much of the Elementary Part of the "Institutiones Physiologicæ" of J. F. Blumenbach, Professor in the University of Gottingen. By John Elliotson, M.D. Cantab. F.R.S. Fifth Edition, 8vo. with numerous Woodcuts, 2*l.* 2*s.* cloth.

THE ENGLISHMAN'S GREEK CONCORDANCE OF THE NEW TESTAMENT; being an attempt at a Verbal Connexion between the Greek and the English Texts; including a Concordance to the Proper Names, with Indexes, Greek-English and English-Greek. 2d Edition, carefully revised, with a new Index, Greek and English. Royal 8vo. 42*s.*

THE ENGLISHMAN'S HEBREW AND CHALDEE CONCORDANCE OF THE OLD TESTAMENT; being an attempt at a Verbal Connexion between the Original and the English Translations: with Indexes, a List of the Proper Names and their occurrences, etc. etc. 2 vols. royal 8vo. 3*l.* 13*s.* 6*d.* cloth; large paper, 4*l.* 14*s.* 6*d.*

EPHEMERA.—A HAND-BOOK OF ANGLING;
Teaching Fly Fishing, Trolling, Bottom Fishing, and Salmon Fishing. With the Natural History of River Fish, and the best Modes of Catching them. By Ephemera (of *Bell's Life in London*). New Edition. Foolscap 8vo. with Wood Engravings, 9*s.* cloth.

ERMAN.—TRAVELS IN SIBERIA;
Including Excursions Northwards, down the Obi, to the Polar Circle, and Southwards, to the Chinese Frontier. By Adolph Erman. Translated by W. D. Cooley, Esq. author of "The History of Maritime and Inland Discovery;" translator and editor of Dr. Parrot's "Journey to Ararat," etc. 2 vols. 8vo. with Map, 31*s.* 6*d.* cloth.

EVANS.—THE SUGAR PLANTER'S MANUAL;
Being a Treatise on the Art of obtaining Sugar from the Sugar Cane. By W. J. Evans, M.D. 8vo. 9*s.* cloth.

FAREY.—TREATISE ON THE STEAM-ENGINE,
Historical, Practical, and Descriptive. By John Farey, Engineer. 4to. illustrated by numerous Woodcuts, and 25 Copper-plates, 5*l.* 5*s* in boards.

FIELD.—PRISON DISCIPLINE;
And the Advantages of the Separate System of Imprisonment: with a detailed Account of the Discipline now pursued in the New County Gaol at Reading. By the Rev. J. Field, M.A. Chaplain. New Edition. 2 vols. 8vo. 20*s.* cloth.

FLOWERS AND THEIR KINDRED THOUGHTS;
A Series of Stanzas—On Hope, Innocence, Modesty, Childhood, Humility, Joy, Love, Constancy, Fascination, Timidity, Fine Taste, Thoughts, Recollection, and Friendship. By Mary Anne Bacon. Illustrated by the Snowdrop, Primrose, Violet, Harebell and Pimpernel, Lily of the Valley, Hawthorn, Rose, Honeysuckle, Carnation, Convolvulus, Fuchsia, Pansy, Forget-me-not, and Holly; designed and printed in Colours by Owen Jones. Imperial 8vo. 31*s.* 6*d.* elegantly bound.

FORSTER (REV. C.)—THE HISTORICAL GEOGRAPHY OF ARABIA;
Or, the Patriarchal Evidences of Revealed Religion. A Memoir, with Illustrative Maps and an Appendix, containing Translations, with an Alphabet and Glossary of the Hamyaritic Inscriptions recently discovered in Hadramaut. By the Rev. Charles Forster, B.D., Rector of Stisted, Essex, author of "Mahometanism Unveiled." 2 vols. 8vo. 30*s.* cloth.

FORSTER (REV. C.)—THE LIFE OF JOHN JEBB, D.D. F.R.S.
Late Bishop of Limerick. With a Selection from his Letters. By the Rev. Charles Forster, B.D., Rector of Stisted, Essex, and one of the Six Preachers in the Cathedral of Christ, Canterbury, formerly Domestic Chaplain to the Bishop. New Edition. 8vo. with Portrait, etc. 16*s.* cloth.

FOSTER.—THE HAND-BOOK OF EUROPEAN LITERATURE.
By Mrs. Foster. Foolscap 8vo. [*In the press.*

FRESENIUS.—A MANUAL OF AGRICULTURAL CHEMISTRY.
By Dr. C. R. Fresenius, Professor of Chemistry and Natural Philosophy, Wiesbaden; late Assistant in the Laboratory of Giessen. Translated from the German. [*In the press.*

FROM OXFORD TO ROME: AND, HOW IT FARED WITH SOME WHO LATELY MADE THE JOURNEY. By a Companion Traveller. New Edition, revised and corrected. Fcp. 8vo. with Frontispiece, 6*s.* cloth.

GARDINER.—SIGHTS IN ITALY:
With some Account of the Present State of Music and the Sister Arts in that Country. By William Gardiner, author of "Sacred Melodies," etc.; Member of the Academy of St. Cecilia, Rome; and of the Class of Fine Arts of the Institut Historique of France. 8vo. with engraved Music, 16*s.* cloth.

GERTRUDE.
A Tale. By the author of "Amy Herbert." Edited by the Rev. William Sewell, B.D., of Exeter College, Oxford. New Edition. 2 vols. foolscap 8vo. 9*s.* cloth.

GIBBON.—HISTORY OF THE DECLINE AND FALL OF THE ROMAN EMPIRE. A new Edition, in One Volume; with an Account of the Author's Life and Writings, by Alexander Chalmers, Esq. F.A.S. 8vo. with Portrait, 18*s.* cloth.
**** *An Edition in* 8 *vols.* 8*vo.* 60*s. boards.*

GOLDSMITH—THE POETICAL WORKS OF OLIVER GOLDSMITH.
Illustrated by Wood Engravings, from Designs by Members of the Etching Club. Edited by Bolton Corney, Esq. Square crown 8vo., uniform with "Thomson's Seasons," 21*s.* cloth; or 36*s.* bound in morocco, by Hayday.

GOWER.—THE SCIENTIFIC PHENOMENA OF DOMESTIC LIFE FAMILIARLY EXPLAINED. By Charles Foote Gower. New Edition. Foolscap 8vo. with Engravings on Wood, 5*s.* cloth.

GRAHAM.—ENGLISH; OR, THE ART OF COMPOSITION
explained in a Series of Instructions and Examples. By G. F. Graham. New Edition, revised and improved. Foolscap 8vo. 6*s.* cloth.

GRANT (MRS.)—LETTERS FROM THE MOUNTAINS.
Being the Correspondence with her Friends, between the years 1773 and 1803. By Mrs. Grant, of Laggan. 6th Edition. Edited, with Notes and Additions, by her Son, J. P. Grant, Esq. 2 vols. post 8vo. 21*s.* cloth.

GRANT (MRS., OF LAGGAN).—MEMOIR AND CORRESPONDENCE
of the late Mrs. Grant, of Laggan, author of "Letters from the Mountains," etc. Edited by her Son, J. P. Grant, Esq. New Edition. 3 vols. post 8vo. Portrait, 1*l.* 11*s.* 6*d.* cloth.

GRAY (THOMAS).—GRAY'S ELEGY,
Written in a Country Churchyard. Illuminated in the Missal style. By Owen Jones, Architect. Imp. 8vo. 31*s.* 6*d.* elegantly bound.

GRAY AND MITCHELL'S ORNITHOLOGY.—THE GENERA OF BIRDS;
Comprising their Generic Characters, a Notice of the Habits of each Genus, and an extensive List of Species, referred to their several Genera. By George Robert Gray, Acad. Imp. Georg. Florent. Soc. Corresp. Senior Assistant of the Zoological Department, British Museum; and author of the "List of the Genera of Birds," etc. Imperial 4to. illustrated with 350 Plates, by David William Mitchell, B.A.

*** In course of publication in Monthly Parts,* 10*s.* 6*d. each; each Part consisting of Four coloured Plates and Three plain, with Letter-press. The Work will not exceed* 50 *Monthly Parts, of which* 48 *have appeared.*

Order I.—Accipitres has been completed, and may be had separately. Imperial 8vo. with 15 coloured and 12 plain Plates, 2*l.* 8*s.* boards.

GRIMBLOT (P.)—LETTERS OF WILLIAM III. AND LOUIS XIV. AND OF THEIR MINISTERS. Illustrating the Domestic and Foreign Policy of England during the period which followed the Revolution of 1688. Extracted from the Archives of France and England, and from Family Papers. Edited by P. Grimblot. 2 vols. 8vo. 30*s.* cloth.

*** Amongst other important and interesting subjects, this work contains the whole of the diplomatic correspondence relative to the Spanish succession, etc.* (1697—1702).

GWILT.—AN ENCYCLOPÆDIA OF ARCHITECTURE;

Historical, Theoretical, and Practical. By Joseph Gwilt, Esq., F.S.A. Illustrated with upwards of 1,000 Engravings on Wood, from Designs by J. S. Gwilt. 8vo. 2*l.* 12*s.* 6*d.* cloth.

HALL.—MIDSUMMER EVE;

A Fairy Tale of Love. By Mrs. S. C. Hall. Square crown 8vo. with nearly 300 Wood Engravings, 21*s.* cloth, gilt edges.

*** *The Illustrations from Designs by D. Maclise, C. Stanfield, T. Creswick, E. M. Ward, A. Elmore, W. E. Frost, J. N. Paton, P. Goodall, T. Landseer, E. H. Wehnert, R. Huskisson, F. W. Topham, K. Meadows, F. W. Fairholt, J. Franklin, J. H. Weir, F. W. Hulme, J. Lecurieux, and T. R. Macquoid; engraved by Green, Dalziel, Bastin, Linton, etc.*

HALL'S (SIDNEY) GENERAL LARGE LIBRARY ATLAS OF FIFTY-THREE MAPS (size 20 in. by 76 in.), with the Divisions and Boundaries carefully coloured; and an Alphabetical Index of all the Names contained in the Maps, with their Latitude and Longitude. An entirely New Edition, corrected throughout from the best and most recent Authorities; with all the Railways laid down, and many of the Maps re-drawn and re-engraved.

*** *Publishing in Monthly Parts, of which* 11 *have appeared. To be completed in* 14 *Parts, price* 6*s. each.*

HALSTED.—LIFE AND TIMES OF RICHARD THE THIRD,

as Duke of Gloucester and King of England: in which all the Charges against him are carefully investigated and compared with the Statements of contemporary Authorities. By Caroline A. Halsted. 2 vols. 8vo. with Portrait and other Illustrations, 1*l.* 10*s.* cloth.

HARRIS.—THE HIGHLANDS OF ÆTHIOPIA;

Being the Account of Eighteen Months' Residence of a British Embassy to the Christian Court of Shoa. By Major Sir W. C. Harris, author of "Wild Sports in Southern Africa," etc. New Edition. 3 vols. 8vo. with Map and Illustrations, 2*l.* 2*s.* cloth.

HARRISON.—ON THE RISE, PROGRESS, AND PRESENT STRUCTURE OF THE ENGLISH LANGUAGE. By the Rev. M. Harrison, M.A., late Fellow of Queen's College, Oxford. Post 8vo. [*In the press.*

HAWBUCK GRANGE;

Or, the Sporting Adventures of Thomas Scott, Esq. By the Author of "Handley Cross; or the Spa Hunt," "Jorrocks' Jaunts and Jollities," etc. 8vo. with eight Illustrations, by Phiz, 12*s.* cloth.

HAWKER.—INSTRUCTIONS TO YOUNG SPORTSMEN

In all that relates to Guns and Shooting. By Lieut.-Col. P. Hawker. 9th edition, corrected, enlarged, and improved, with Eighty-five Plates and Woodcuts, by Adlard and Branston, from Drawings by C. Varley, Dicks, etc. 8vo. 21*s.* cloth.

HAYDON.—THE AUTOBIOGRAPHY AND JOURNALS OF THE LATE B. R. HAYDON, Historical Painter. [*In preparation.*

HAYDON (B. R.)—LECTURES ON PAINTING AND DESIGN,

Delivered at the London Institution, the Royal Institution, Albermarle Street, to the University of Oxford, etc. By B. R. Haydon, Historical Painter. 2 vols. 8vo. with Portraits of the Author and Sir David Wilkie, and numerous other Illustrations, 24*s.* cloth.

HINTS ON ETIQUETTE AND THE USAGES OF SOCIETY:

With a Glance at Bad Habits. By Ἀγωγός. "Manners make the Man." New Edition, revised (with additions) by a Lady of Rank. Foolscap 8vo. 2*s.* 6*d.* cloth.

HISTORICAL CHARADES.

By the Author of "Letters from Madras." Foolscap 8vo. 5*s.* cloth.

HISTORICAL PICTURES OF THE MIDDLE AGES,

In Black and White. Made on the spot, from Records in the Archives of Switzerland. By a Wandering Artist. 2 vols. post 8vo. 18*s.* cloth.

HOARE.—A DESCRIPTIVE ACCOUNT OF A NEW METHOD OF PLANTING AND MANAGING THE ROOTS OF GRAPE VINES. By Clement Hoare, author of "A Treatise on the Cultivation of the Grape Vine on Open Walls." 12mo. 5*s.* cl.

HOARE—A PRACTICAL TREATISE ON THE CULTIVATION OF THE GRAPE VINE ON OPEN WALLS. By Clement Hoare. New Edition. 8vo. *7s. 6d.* cloth.

HOBBES.—THE COMPLETE WORKS OF THOMAS HOBBES,

Of Malmesbury; now first collected, and edited by Sir William Molesworth, Bart. 16 vols. 8vo. *8l.* cloth.

*** *Separately, the English Works, in 11 vols. 5l. 10s.; the Latin Works, in 5 vols. 2l. 10s.*

HOLLAND.—MEDICAL NOTES AND REFLECTIONS.

By Henry Holland, M.D. F.R.S. etc. Fellow of the Royal College of Physicians, Physician Extraordinary to the Queen, and Physician in Ordinary to His Royal Highness Prince Albert. New Edition. 8vo. *18s.* cloth.

HOOK (DR. W. F.)—THE LAST DAYS OF OUR LORD'S MINISTRY;

A Course of Lectures on the principal Events of Passion Week. By Walter Farquhar Hood, D.D., Vicar of Leeds, Prebendary of Lincoln, and Chaplain in Ordinary to the Queen. New Edition. Foolscap 8vo. *6s.* cloth.

HOOKER.—KEW GARDENS;

Or a Popular Guide to the Royal Botanic Gardens of Kew. By Sir William Jackson Hooker, K.H. D.C.L. F.R.A. & L.S. etc. etc. Director. New Edition. 16mo. with numerous Wood Engravings, *6d.* sewed.

HOOKER.—THE BRITISH FLORA.

Comprising the Phænogamous or Flowering Plants, and the Ferns. By Sir William Jackson Hooker, K.H. LL.D. F.R.A. and L.S. etc. etc. etc. New Edition, with Additions and Corrections; and 173 Figures, illustrative of the Umbelliferous Plants, the Composite Plants, the Grasses, and the Ferns. Vol. I. 8vo., with 12 Plates, *14s.* plain; with the Plates coloured, *24s.* cloth.

Vol. II. in Two Parts, comprising the Cryptogamia and the Fungi, completing the British Flora, and forming Vol. V., Parts 1 and 2, of Smith's English Flora, *24s.* boards.

HORNE (THE REV. T. H.)—AN INTRODUCTION TO THE CRITICAL STUDY AND KNOWLEDGE OF THE HOLY SCRIPTURES. By the Rev. Thomas Hartwell Horne, B.D. of St. John's College, Cambridge. New Edition, revised and corrected. 5 vols. 8vo. with Maps and Fac-similes, *3l. 3s.* cloth; or *5l.* bound in calf by Hayday.

HORNE (THE REV. T. H.)—A COMPENDIOUS INTRODUCTION TO THE STUDY OF THE BIBLE. By the Rev. Thomas Hartwell Horne, B.D. of St. John's College, Cambridge. Being an Analysis of his "Introduction to the Critical Study and Knowledge of the Holy Scriptures." New Edition. 12mo. with Maps and Engravings, *9s.* boards.

HOWITT, (MARY).—BALLADS AND OTHER POEMS.

By Mary Howitt. Square crown 8vo. with a Portrait from a Picture by Miss Gillies, beautifully engraved by W. H. Egleton, *18s.* cloth; morocco, *36s.* *(bound by Hayday).*

HOWITT.—THE CHILDREN'S YEAR.

By Mary Howitt. With Four Illustrations, engraved by John Absolon, from Original Designs by Anna Mary Howitt. Square 16mo. *5s.* cloth.

HOWITT.—THE BOY'S COUNTRY BOOK:

Being the real Life of a Country Boy, written by Himself; exhibiting all the Amusements, Pleasures, and Pursuits of Children in the Country. Edited by William Howitt, author of "The Rural Life of England," etc. New Edition. Fcap. 8vo. with 40 Woodcuts, *6s.* cloth.

HOWITT.—VISITS TO REMARKABLE PLACES;

Old Halls, Battle-Fields, and Scenes illustrative of Striking Passages in English History and Poetry. By William Howitt. New Edition. Medium 8vo. with 40 Illustrations, *21s.* cloth.

SECOND SERIES, chiefly in the Counties of DURHAM and NORTHUMBERLAND, with a Stroll along the BORDER. Medium 8vo. with upwards of 40 highly-finished Woodcuts, from Drawings made on the spot, *21s.* cloth.

HOWITT.—THE RURAL LIFE OF ENGLAND.

By William Howitt. New Edition, corrected and revised. Medium 8vo. with Engravings on Wood by Bewick and Williams, uniform with "Visits to Remarkable Places," 21*s.* cloth.

HOWITT.—THE RURAL AND DOMESTIC LIFE OF GERMANY:

With Characteristic Sketches of its chief Cities and Scenery. Collected in a General Tour, and during a Residence in that Country in the Years 1840-42. By William Howitt, author of "The Rural Life of England," etc. Medium 8vo., with above 50 Illustrations, 21*s.* cloth.

HOWITT.—THE STUDENT-LIFE OF GERMANY.

From the Unpublished MS. of Dr. Cornelius. By William Howitt. 8vo. with 24 Wood Engravings, and 7 Steel Plates, 21*s.* cloth.

HOWITT.—COLONISATION AND CHRISTIANITY:

A Popular History of the Treatment of the Natives, in all their Colonies, by the Europeans. By William Howitt. Post 8vo. 10*s.* 6*d.* cloth.

HUDSON.—PLAIN DIRECTIONS FOR MAKING WILLS

In conformity with the Law, and particularly with reference to the Act 7 Wm. IV. and 1 Vict. c. 26. To which is added, a clear Exposition of the Law relating to the Distribution of Personal Estate in the case of Intestacy, with two Forms of Wills, and much useful Information, etc. By J. C. Hudson, Esq. New Edition, corrected. Fcap. 8vo. 2*s.* 6*d.* cloth.

HUDSON.—THE EXECUTOR'S GUIDE.

By J. C. Hudson, Esq., of the Legacy Duty Office, London: author of "Plain Directions for Making Wills," and "The Parent's Hand-Book." New Edition. Foolscap 8vo. 5*s.* cloth.

**** ***The above two works may be had in One volume, price 7s. cloth.***

HUMBOLDT (BARON).—COSMOS:

A Sketch of a Physical Description of the Universe. Translated, with the Author's sanction and co-operation, under the superintendence of Lieutenant-Colonel Edward Sabine, F.R.S. For. Sec. R.S. New Edition. Vols. I. and II. post 8vo. 12*s.* each, cloth.

"*Je vous autorise, Monsieur, de vous servir en toute occasion de la déclaration, que la belle traduction du Colonel Sabine, enrichie de rectifications et de notes très-précieuses, et qui ont toute mon approbation, est la seule par laquelle j'ai vivement desiré voir introduit mon ouvrage dans la littérature de votre pays.*"—Baron Humboldt to Mr. Murray.

HUME.—THE LEARNED SOCIETIES AND PRINTING CLUBS OF THE

UNITED KINGDOM; being an Account of their respective Origin, History, Objects, and Constitution: full details respecting Membership, Fees, their published Works and Transactions, Notices of their Periods and Places of Meeting, etc. With a general Introduction, and a Classified Index. Compiled from Official Documents, by the Rev. A. Hume, LL.D., F.S.A. Post 8vo. 8*s.* 6*d.* cloth.

HUNT.—RESEARCHES ON LIGHT:

An Examination of all the Phenomena connected with the Chemical and Molecular Changes produced by the Influence of the Solar Rays; embracing all the known Photographic Processes, and new Discoveries in the Art. By Robert Hunt, Keeper of Mining Records, Museum of Economic Geology. 8vo. with Plate and Woodcuts, 10*s.* 6*d.* cloth.

JAMES.—A HISTORY OF THE LIFE OF EDWARD THE BLACK PRINCE,

and of various Events connected therewith, which occurred during the Reign of Edward III. King of England. By G. P. R. James, Esq. New Edition. 2 vols. foolscap 8vo. with Map, 15*s.*

JAMESON.—SACRED AND LEGENDARY ART.

By Mrs. Jameson. 2 vols. square crown 8vo., illustrated by numerous Woodcuts, with a few Etchings by the Author. [*Nearly ready.*

Vol. I. contains Legends of the Angels and Archangels, the Evangelists, the Apostles, the Doctors of the Church, and Mary Magdalene.

Vol. II. contains Legends of the Patron Saints, the Virgin Patronesses, the Greek and Latin Martyrs, the Bishops and Confessors, the Hermits, and the Warrior Saints of Christendom.

JEBB (BISHOP) AND KNOX (ALEXANDER).—THIRTY YEARS' COR-

RESPONDENCE between John Jebb, D.D. F.R.S., Bishop of Limerick, Ardfert, Aghadoe, and Alexander Knox, Esq. M.R.I.A. Edited by the Rev. Charles Forster, B.D. Rector of Stisted, formerly Domestic Chaplain to Bishop Jebb. New Edition. 2 vols. 8vo. 28*s.* cloth.

JEBB.—A LITERAL TRANSLATION OF THE BOOK OF PSALMS;

Intended to illustrate their Poetical and Moral Structure. To which are added, Dissertations on the word "Selah," and on the Authorship, Order, Titles, and Poetical Features of the Psalms. By the Rev. John Jebb, A.M., Rector of Peterstow. 2 vols. 8vo. 21*s.* cloth.

JEFFREY (LORD).—CONTRIBUTIONS TO THE EDINBURGH REVIEW.

By Francis Jeffrey, now one of the Judges in the Court of Session in Scotland. New Edit. 3 vols. 8vo. 42*s.* cloth.

JOHNSON.—THE WISDOM OF THE RAMBLER, ADVENTURER, AND IDLER. Consisting of 110 of the best Essays. By Samuel Johnson, LL.D. Foolscap 8vo. 7*s.* cloth.

JOHNSON.—THE FARMER'S ENCYCLOPÆDIA,

And DICTIONARY of RURAL AFFAIRS: embracing all the recent Discoveries in Agricultural Chemistry; adapted to the comprehension of unscientific Readers. By Cuthbert W. Johnson, Esq., F.R.S. Barrister-at-Law, Editor of the "Farmers' Almanack," etc. 8vo. with Wood Engravings, 2*l.* 10*s.* cloth.

JONES'S GUIDE TO NORWAY, AND SALMON-FISHER'S POCKET COMPANION; founded on Experience collected in the Country. Edited by Frederic Tolfrey, Esq., author of "The Sportsman in France," and "The Sportsman in Canada." Foolscap 8vo. with Frontispiece and Vignette Title, and Engravings of the proper Flies, beautifully coloured, in exact imitation of the originals, 15*s.* cloth.

KINDERSLEY.—THE VERY JOYOUS, PLEASANT, AND REFRESHING HISTORY of the Feats, Exploits, Triumphs, and Achievements of the Good Knight, without Fear and without Reproach, the gentle Lord De Bayard. Set forth in English by Edward Cockburn Kindersley, Esq. Square post 8vo. with Ornamental Headings, and Frontispiece by E. H. Wehnert, 9*s.* 6*d.* cloth.

KIP.—THE CHRISTMAS HOLYDAYS IN ROME.

By the Rev. W. Ingraham Kip, M.A. Edited by the Rev. W. Sewell, B.D. Fellow and Tutor of Exeter College, Oxford. Foolscap 8vo. 5*s.* cloth.

KIRBY AND SPENCE.—AN INTRODUCTION TO ENTOMOLOGY;

Or, Elements of the Natural History of Insects: comprising an account of noxious and useful Insects, of their Metamorphoses, Food, Stratagems, Habitations, Societies, Motions, Noises, Hybernation, Instinct, etc. By W. Kirby, M.A. F.R.S. & L.S. Rector of Barham; and W. Spence, Esq., F.R.S. & L.S. New Edition, enlarged. 2 vols. 8vo. 31*s.* 6*d.* cloth.

KNOX (ALEXANDER). — REMAINS OF ALEXANDER KNOX, ESQ.

Of Dublin, M.R.I.A.; containing Essays, chiefly explanatory, of Christian Doctrine; and Confidential Letters, with Private Papers, illustrative of the Writer's Character, Sentiments, and Life. New Edition. 4 vols. 8vo. 2*l.* 8*s.* cloth.

LAING.—THE CHRONICLE OF THE KINGS OF NORWAY,

From the Earliest Period of the History of the Northern Sea Kings to the Middle of the Twelfth Century: commonly called the Heimskringla. Translated from the Icelandic of Snorro Sturleson, with Notes, and a Preliminary Discourse, by Samuel Laing, Esq. 3 vols. 8vo. 36*s.* cloth.

LAING.—A TOUR IN SWEDEN

In 1838; comprising Observations on the Moral, Political, and Economical State of the Swedish Nation. By Samuel Laing, Esq. 8vo. 12*s.* cloth.

LANE (R. I.)—LIFE AT THE WATER CURE:

Or, a Month at Malvern. A Diary of Facts and Fancies. To which is added the Sequel. By Richard J. Lane, A.R.A., Lithographer in Ordinary to Her Majesty and His Royal Highness Prince Albert. Post 8vo. with many Illustrations, 14*s.* cloth.

L. E. L.—THE POETICAL WORKS OF LETITIA ELIZABETH LANDON.

New Edition. 4 vols. foolscap 8vo. with Illustrations by Howard, etc. 28*s.* cloth; or bound in morocco, with gilt edges, 2*l.* 4*s.*

The following Works separately:—

The IMPROVISATRICE - - 10*s.* 6*d.*	The GOLDEN VIOLET - - - 10*s.* 6*d.*
The VENETIAN BRACELET - 10*s.* 6*d.*	The TROUBADOUR - - - - 10*s.* 6*d.*

LARDNER'S CABINET CYCLOPÆDIA;

Being a Series of Original Works on History, Biography, Natural Philosophy, Natural History, Literature, the Sciences, Arts, and Manufactures. By Bishop Thirlwall, Sir James Mackintosh, Sir John Herschel, Sir Walter Scott, Thomas Moore, Robert Southey, and other Eminent Writers. Conducted and edited by Dr. Lardner.

The Series complete in One Hundred and Thirty-three Volumes, 39*l.* 18*s.* The Works separately, 6*s.* per volume.

The Series comprises:—

1. Bell's History of Russia . 3 vols. 18*s.*
2. Bell's Lives of British Poets 2 vols. 12*s.*
3. Brewster's Treatise on Optics 1 vol. 6*s.*
4. Cooley's History of Maritime and Inland Discovery . 3 vols. 18*s.*
5. Crowe's History of France . 3 vols. 18*s.*
6. De Morgan's Treatise on Probabilities . . . . 1 vol. 6*s.*
7. De Sismondi's History of the Italian Republics . . 1 vol. 6*s.*
8. De Sismondi's Fall of the Roman Empire . . . 2 vols. 12*s.*
9. Donovan's Treatise on Chemistry . . . . . 1 vol. 6*s.*
10. Donovan's Domestic Economy, 2 vols. 12*s.*
11. Dunham's History of Spain and Portugal . . . 5 vols. 30*s.*
12. Dunham's History of Denmark, Sweden, and Norway . . . . . 3 vols. 18*s.*
13. Dunham's History of Poland 1 vol. 6*s.*
14. Dunham's History of the Germanic Empire . . 3 vols. 18*s.*
15. Dunham's History of Europe during the Middle Ages . 4 vols. 24*s.*
16. Dunham's Lives of British Dramatists . . . 2 vols. 12*s.*
17. Dunham's Lives of Early Writers of Great Britain . 1 vol. 6*s.*
18. Fergus's History of the United States . . . 2 vols. 12*s.*
19. Fosbroke's Grecian and Roman Antiquities . . 2 vols. 12*s.*
20. Forster's Lives of the Statesmen of the Commonwealth 5 vols. 30*s.*
21. Forster, Mackintosh, and Courtenay's Lives of British Statesmen . . 7 vols. 42*s.*
22. Gleg's Lives of Military Commanders . . . . . 3 vols. 18*s.*
23. Grattan's History of the Netherlands . . . 1 vol. 6*s.*
24. Henslow's Treatise on Botany . . . . . 1 vol. 6*s.*
25. Herschel's Treatise on Astronomy . . . . . 1 vol. 6*s.*
26. Herschel's Preliminary Discourse on the Study of Natural Philosophy . . 1 vol. 6*s.*
27. History of Rome . . . 2 vols. 12*s.*
28. History of Switzerland . . 1 vol. 6*s.*
29. Holland's Treatise on the Manufactures in Metal . 3 vols. 18*s.*
30. James's Lives of Foreign Statesmen . . . . 5 vols. 30*s.*
31. Kater and Lardner's Treatise on Mechanics . . . 1 vol. 6*s.*
32. Keightley's Outlines of History . . . . . 1 vol. 6*s.*
33. Lardner's Treatise on Arithmetic . . . . . 1 vol. 6*s.*
34. Lardner's Treat. on Geometry 1 vol. 6*s.*
35. Lardner's Treatise on Heat . 1 vol. 6*s.*
36. Lardner's Treatise on Hydrostatics and Pneumatics . 1 vol. 6*s.*
37. Lardner and Walker's Electricity and Magnetism . 2 vols. 12*s.*
38. Mackintosh, Wallace, and Bell's History of England, 10 vols. 60*s.*
39. Montgomery and Shelley's Lives of Italian, Spanish, and Portuguese Authors . 3 vols. 18*s.*
40. Moore's History of Ireland . 4 vols. 24*s.*
41. Nicolas's Chronology of History . . . . . 1 vol. 6*s.*
42. Phillips's Treat. on Geology 2 vols. 12*s.*
43. Powell's History of Natural Philosophy . . . 1 vol. 6*s.*
44. Porter's Treatise on the Manufacture of Silk . . 1 vol. 6*s.*
45. Porter's Treatise on the Manufacture of Porcelain and Glass . . . . . 1 vol. 6*s.*
46. Roscoe's Lives of British Lawyers . . . . 1 vol. 6*s.*
47. Scott's History of Scotland . 2 vols. 12*s.*
48. Shelley's Lives of French Authors . . . . 2 vols. 12*s.*
49. Shuckard and Swainson's Treatise on Insects . . 1 vol. 6*s.*
50. Southey's Lives of British Admirals . . . . 5 vols. 30*s.*
51. Stebbing's History of the Church . . . . 2 vols. 12*s.*
52. Stebbing's History of the Reformation . . . 2 vols. 12*s.*
53. Swainson's Preliminary Discourse on Natural History, 1 vol. 6*s.*
54. Swainson's Natural History and Classification of Animals . . . . . 1 vol. 6*s.*
55. Swainson's Habits and Instincts of Animals . . 1 vol. 6*s.*
56. Swainson's Quadrupeds . 1 vol. 6*s.*
57. Swainson's Birds . . . 2 vols. 12*s.*
58. Swainson's Fish, Reptiles, etc. . . . . 2 vols. 12*s.*
59. Swainson's Shells and Shellfish . . . . . 1 vol. 6*s.*
60. Swainson's Animals in Menageries . . . . 1 vol. 6*s.*
61. Swainson's Taxidermy and Bibliography . . . 1 vol. 6*s.*
62. Thirlwall's History of Greece 8 vols. 48*s.*

LANETON PARSONAGE:
A Tale for Children, on the practical use of a portion of the Church Catechism. By the author of "Amy Herbert," and "Gertrude." Edited by the Rev. W. Sewell, B.D. New Edition. Parts I. and II. fcap. 8vo. 5s. each, cloth.

LATHAM.—ON DISEASES OF THE HEART.
Lectures on Subjects connected with Clinical Medicine; comprising Diseases of the Heart. By P. M. Latham, M.D. Physician Extraordinary to the Queen; and late Physician to St. Bartholomew's Hospital. New Edition. 2 vols. 12mo. 16s. cloth.

LEE.—TAXIDERMY;
Or, the Art of Collecting, Preparing, and Mounting Objects of Natural History. For the use of Museums and Travellers. By Mrs. R. Lee. New Edition, improved; with an account of a Visit to Walton Hall, and Mr. Waterton's Method of Preserving Animals. Fcap. 8vo. with Woodcuts, 7s.

LEE.—ELEMENTS OF NATURAL HISTORY,
For the Use of Schools and Young Persons: comprising the Principles of Classification, interspersed with amusing and instructive Accounts of the most remarkable Animals. By Mrs. R. Lee. 12mo. with 56 Woodcuts, 7s. 6d. bound.

LEMPRIÈRE.—A CLASSICAL DICTIONARY;
Containing a copious Account of all the Proper Names mentioned in Ancient Authors; with the Value of Coins, Weights, and Measures, used amongst the Greeks and Romans; and a Chronological Table. By T. Lemprière, D.D. New Edition, corrected. 8vo. 9s. cloth.

LESLIE (C.R.)—MEMOIRS OF THE LIFE OF JOHN CONSTABLE, ESQ.
R.A. Composed chiefly of his Letters. By C.R. Leslie, R.A. Second Edition, with further Extracts from his Correspondence. Small 4to. with two Portraits (one from a new Sketch, by Mr. Leslie,) and a plate of "Spring," engraved by Lucas, 21s. cloth.

LETTERS TO MY UNKNOWN FRIENDS.
By a Lady. New Edition. Foolscap 8vo. 6s. 6d. cloth.

LINDLEY.—AN INTRODUCTION TO BOTANY.
By Prof. J. Lindley, Ph.D. F.R.S. L.S. etc. New Edition, with Corrections and considerable Additions. 8vo. with Six Plates and numerous Woodcuts, 18s. cloth.

LINDLEY.—A SYNOPSIS OF THE BRITISH FLORA,
Arranged according to the Natural Orders. By Professor John Lindley, Ph. D., F.R.S., etc. New Edition, with numerous Additions and Improvements. 12mo. 10s. 6d. cloth.

LINDLEY.—THE THEORY OF HORTICULTURE;
Or, an Attempt to Explain the Principal Operations of Gardening upon Physiological Principles. By John Lindley, Ph.D. F.R.S. 8vo. with Illustrations on Wood, 12s. cloth.

LINDLEY.—GUIDE TO THE ORCHARD AND KITCHEN GARDEN;
Or, an Account of the most valuable Fruits and Vegetables cultivated in Great Britain: with Kalendars of the Work required in the Orchard and Kitchen Garden during every Month in the Year. By George Lindley, C.M.H.S. Edited by Professor Lindley. 8vo. 16s. boards.

LINWOOD (W.)—ANTHOLOGIA OXONIENSIS;
Sive, Florilegium e lusibus poeticis diversorum Oxoniensium Græcis et Latinis concerptum. Curante Gulielmo Linwood, M.A. Ædis Christi Alumno. 8vo. 14s. cloth.

LOUDON (MRS.)—THE AMATEUR GARDENER'S CALENDAR;
Being a Monthly Guide, as to what should be avoided as well as what should be done in a Garden in each Month: with plain Rules *how to do* what is requisite; Directions for laying out and planting Kitchen and Flower Gardens, Pleasure Grounds, and Shrubberies; and a short account, in each Month, of the Quadrupeds, Birds, and Insects, then most injurious to Gardens. By Mrs. Loudon. 16mo. with numerous Wood Engravings, 7s. 6d. cloth.

LOUDON (MRS.)—THE LADY'S COUNTRY COMPANION;
Or, How to Enjoy a Country Life Rationally. By Mrs. Loudon, author of "Gardening for Ladies," etc. New Edition. Foolscap 8vo., with Plate and Woodcuts, 7s. 6d. cloth.

LOUDON (J. C.)—SELF-INSTRUCTION FOR YOUNG GARDENERS,
Foresters, Bailiffs, Land Stewards, and Farmers; in Arithmetic, Book-keeping, Geometry, Mensuration, Practical Trigonometry, Mechanics, Land-Surveying, Levelling, Planning and Mapping, Architectural Drawing, and Isometrical Projection and Perspective; with Examples shewing their applications to Horticultural and Agricultural Purposes. By the late J. C. Loudon, F.L.S. H.S. etc. With a Portrait of Mr. Loudon, and a Memoir by Mrs. Loudon. 8vo. with Wood Engravings, 7s. 6d. cloth.

LOUDON.—AN ENCYCLOPÆDIA OF TREES AND SHRUBS;
Being the "Arboretum et Fruticetum Britannicum" abridged; containing the Hardy Trees and Shrubs of Great Britain, Native and Foreign, scientifically and popularly described: with their Propagation, Culture, and Uses in the Arts. By J. C. Loudon, F.L.S. etc. 8vo. with upwards of 2,000 Engravings on Wood, 2*l.* 10*s.* cloth.

A New Edition of the Original Work, in 8 vols. 8vo. with above 400 octavo Plates of Trees, and upwards of 2,500 Woodcuts, 10*l.* cloth.

LOUDON.—AN ENCYCLOPÆDIA OF GARDENING;
Presenting in one systematic view, the History and Present State of Gardening in all Countries, and its Theory and Practice in Great Britain: with the Management of the Kitchen Garden, the Flower Garden, Laying-out Grounds, etc. By J. C. Loudon, F.L.S. etc. A new Edition. 8vo. with nearly 1,000 Engravings on Wood, 2*l.* 10*s.* cloth.

LOUDON.—AN ENCYCLOPÆDIA OF AGRICULTURE;
Comprising the Theory and Practice of the Valuation, Transfer, Laying-out, Improvement, and Management of Landed Property, and of the cultivation and economy of the Animal and Vegetable Productions of Agriculture, including all the latest improvements. By J. C. Loudon, F.L.G.Z. and H.S. etc. Fifth Edition. 8vo. with upwards of 1,100 Engravings on Wood, by Branston, 2*l.* 10*s.* cloth.—The Supplement, *separately*, 5*s.* sewed.

LOUDON.—AN ENCYCLOPÆDIA OF PLANTS;
Including all the Plants which are now found in, or have been introduced into, Great Britain; giving their Natural History, accompanied by such Descriptions, Engraved Figures, and Elementary Details, as may enable a beginner, who is a mere English reader, to discover the name of every Plant which he may find in flower, and acquire all the information respecting it which is useful and interesting. By J. C. Loudon, F.L.S., etc. The Specific Characters by an Eminent Botanist; the Drawings by J. D. C. Sowerby, F.L.S. A new Edition, with a new Supplement and a new Index. 8vo. with nearly 10,000 Wood Engravings, 73*s.* 6*d.* cloth.

LOUDON.—AN ENCYCLOPÆDIA OF COTTAGE, FARM, AND VILLA ARCHITECTURE and FURNITURE. Containing Designs for Cottages, Villas, Farm Houses, Farmeries, Country Inns, Public Houses, Parochial Schools, etc.; with the requisite Fittings-up, Fixtures, and Furniture, and appropriate Offices, Gardens, and Garden Scenery: each Design accompanied by Analytical and Critical Remarks. By J. C. Loudon, F.L.S. etc. New Edition, Edited by Mrs. Loudon. 8vo. with more than 2,000 Engravings on Wood, 63*s.* cloth.—The Supplement, *separately*, 8vo. 7*s.* 6*d.* sewed.

LOUDON.—HORTUS BRITANNICUS:
A Catalogue of all the Plants indigenous to or introduced into Britain. New Edition, with a Supplement, prepared, under the direction of J. C. Loudon, by W. H. Baxter, and revised by George Don, F.L.S. 8vo. 31*s.* 6*d.* cloth.

LOUDON.—THE SUBURBAN GARDENER AND VILLA COMPANION:
Comprising the Choice of a Villa or Suburban Residence, or of a Situation on which to form one; the Arrangement and Furnishing of the House; and the Laying-out, Planting, and general Management of the Garden and Ground; the whole adapted for Grounds from one perch to fifty acres and upwards in extent; intended for the instruction of those who know little of Gardening or Rural Affairs, and more particularly for the use of Ladies. By J. C. Loudon, F.L.S., etc. 8vo. with above 300 Wood Engravings, 20*s.* cloth.

LOUDON.—HORTUS LIGNOSUS LONDINENSIS;
Or, a Catalogue of all the Ligneous Plants cultivated in the neighbourhood of London. To which are added their usual Prices in Nurseries. By J. C. Loudon, F.L.S. etc. 8vo. 7*s.* 6*d.*

LOW.—ON LANDED PROPERTY, AND THE ECONOMY OF ESTATES;
Comprehending the Relations between Landlord and Tenant, and the Principles and Forms of Leases; of Farm Buildings, Enclosures, Drains, Embankments, Roads, and other Rural Works, Minerals, and Woods. By David Low, Esq. F.R.S.E. etc., author of "Elements of Practical Agriculture," etc. 8vo. with numerous Wood Engravings, 21*s.* cloth.

LOW.—AN INQUIRY INTO THE NATURE OF THE SIMPLE BODIES OF CHEMISTRY. By D. Low, F.R.S.E. Professor of Agriculture in the University of Edinburgh; author of "Elements of Practical Agriculture," "A Treatise on Landed Property and the Economy of Estates," "A Treatise on the Breeds of the British Domesticated Animals," "The Breeds of the Domesticated Animals of Great Britain Illustrated and Described." 2d Edition, enlarged and improved. 8vo. 9*s.* cloth.

LOW.—ON THE DOMESTICATED ANIMALS OF GREAT BRITAIN,
Comprehending the Natural and Economical History of the Species and Breeds; Illustrations of the Properties of External Form; and Observations on the Principles and Practice of Breeding. By David Low, Esq., F.R.S.E., Professor of Agriculture in the University of Edinburgh, etc.; author of "Elements of Practical Agriculture," etc. 8vo. with Engravings on Wood, 25*s.* cloth.

LOW.—THE BREEDS OF THE DOMESTICATED ANIMALS OF GREAT BRITAIN described. By David Low, Esq. F.R.S.E., Professor of Agriculture in the University of Edinburgh, etc. The Plates from drawings by W. Nicholson, R.S.A., reduced from a Series of Oil Paintings, executed for the Agricultural Museum of the University of Edinburgh, by W. Shiels, R.S.A. 2 vols. atlas quarto, with 56 Plates of Animals, beautifully coloured after Nature, 16*l*. 16*s*. half-bound in morocco.

Or in four separate portions, as follow:—

The OX. 1 Vol. With 22 Plates, price 6*l*. 16*s*. 6*d*. half-bound morocco.
The SHEEP. 1 Vol. With 21 Plates, price 6*l*. 16*s*. 6*d*. half-bound morocco.
The HORSE. 1 Vol. With 8 Plates, price 3*l*. half-bound morocco.
The HOG. 1 Vol. With 5 Plates, price 2*l*. 2*s*. half bound morocco.

LOW.—ELEMENTS OF PRACTICAL AGRICULTURE;
Comprehending the Cultivation of Plants, the Husbandry of the Domestic Animals, and the Economy of the Farm. By David Low, Esq. F.R.S.E., Professor of Agriculture in the University of Edinburgh. New Edition. 8vo. with an entirely new set of above 200 Woodcuts, 21*s*. cloth.

MACAULAY.—CRITICAL AND HISTORICAL ESSAYS CONTRIBUTED TO THE EDINBURGH REVIEW. By the Right Hon. Thomas Babington Macaulay, M.P. New Edition. 3 vols. 8vo. 36*s*. cloth.

MACAULAY.—THE HISTORY OF ENGLAND.
From the Accession of James II. By Thomas Babington Macaulay. Vols. I. and II. 8vo.
[In the press.

MACAULAY.—LAYS OF ANCIENT ROME.
With "Ivry" and "The Armada." By the Right Honorable Thomas Babington Macaulay, M.P. New Edition. 16mo. 4*s*. 6*d*. cloth; morocco, 10*s*. 6*d*. (*by Hayday*).

MACAULAY.—MR. MACAULAY'S LAYS OF ANCIENT ROME.
A New Edition. With numerous Illustrations, Original and from the Antique, drawn on Wood by George Scharf, jun.; and engraved by Samuel Williams. Fcp. 4to. 21*s*. boards; morocco, 42*s*. (*bound by Hayday*).

MACKAY (CHARLES).—THE SCENERY AND POETRY OF THE ENGLISH LAKES: a Summer Ramble. By Charles Mackay, Esq. LL.D. author of "Legends of the Isles," "The Salamandrine," "The Thames and its Tributaries," etc. 8vo. with beautiful Wood Engravings from Original Sketches, 14*s*. cloth.

MACKINTOSH (SIR JAMES).—THE LIFE OF SIR THOMAS MORE.
By the Right Hon. Sir James Mackintosh. Reprinted from the Cabinet Cyclopædia. Foolscap 8vo. with Portrait, 5*s*. cloth; or bound in vellum, 8*s*.

MACKINTOSH'S (SIR JAMES) MISCELLANEOUS WORKS;
Including his Contributions to The EDINBURGH REVIEW. Edited by Robert James Mackintosh, Esq. 3 vols. 8vo. 42*s*. cloth.

M'CULLOCH.—A DICTIONARY, GEOGRAPHICAL, STATISTICAL, AND HISTORICAL, of the various Countries, Places, and Principal Natural Objects in the World. By J. R. M'Culloch, Esq. A new Edition. 2 vols. 8vo. with Six large Maps, 4*l*. cloth.

*** *The new Articles are printed separately as a Supplement to the former Edition. They comprise a full account of the present state of the United Kingdom, the Oregon Territory, etc.* 8vo. 5*s*. *sewed.*

M'CULLOCH.—A DICTIONARY, PRACTICAL, THEORETICAL, AND HISTORICAL, OF COMMERCE, AND COMMERCIAL NAVIGATION. By J. R. M'Culloch, Esq. A New Edition, corrected, enlarged, and improved. 8vo. with Maps and Plans, 50*s*. cloth; or 55*s*. strongly half-bound in russia.

A SUPPLEMENT *to the Editions published in* 1844 *and* 1846 *may be had separately, price* 4*s*. 6*d*. *sewed.*

M'CULLOCH.—A TREATISE ON THE SUCCESSION TO PROPERTY VACANT BY DEATH: including Inquiries into the Influence of Primogeniture, Entails, the Law of Compulsory Partition, Foundations, etc. over the Public Interests. By J. R. M'Culloch, Esq. 8vo. 8*s*. 6*d*. cloth.

M'CULLOCH (J. R.)—AN ACCOUNT, DESCRIPTIVE, AND STATISTICAL, of the BRITISH EMPIRE; exhibiting its Extent, Physical Capacities, Population, Industry, and Civil and Religious Institutions. By J. R. M'Culloch, Esq. 3d Edition, corrected, enlarged, and greatly improved. 2 thick vols. 8vo. 42*s*. cloth.

M'CULLOCH.—THE LITERATURE OF POLITICAL ECONOMY;
Being a Classified Catalogue of the principal Works in the different departments of Political Economy, interspersed with Historical, Critical, and Biographical Notices. By J. R. M'Culloch, Esq. 8vo. 14*s.* cloth.

M'CULLOCH.—A TREATISE ON THE PRINCIPLES AND PRACTICAL INFLUENCE OF TAXATION AND THE FUNDING SYSTEM. By J. R. M'Culloch, Esq. 8vo. 10*s.* cloth.

MADAME DE MALCUET:
A Tale of 1820. 3 vols. post 8vo. 31*s.* 6*d.* boards.

"One of the most fascinating productions of the present day. The story is well told; and the incidents are all grouped together with the skill of a painter and the hand of a master. Few works of fiction have appeared at any time, and fewer still in more recent days, which will bear any comparison with this, in all the essential attributes of a good novel."
Observer.

MAITLAND (DR. CHARLES).—THE CHURCH IN THE CATACOMBS:
A Description of the Primitive Church of Rome, illustrated by its Sepulchral Remains. By Charles Maitland, M.D. New Edition, revised. 8vo. with numerous Engravings on Wood. 14*s.* cloth.

MARCET.—CONVERSATIONS ON CHEMISTRY;
In which the Elements of that Science are familiarly Explained and Illustrated by Experiments. By Mrs. Marcet. New Edition, corrected. 2 vols. foolscap 8vo. 14*s.* cloth.

MARCET.—CONVERSATIONS ON NATURAL PHILOSOPHY;
In which the Elements of that Science are familiarly explained, and adapted to the comprehension of Young Persons. By Mrs. Marcet. New Edition, enlarged and corrected. Fcap. 8vo. with 23 Plates, 10*s.* 6*d.* cloth.

MARCET.—CONVERSATIONS ON POLITICAL ECONOMY;
In which the Elements of that Science are familiarly explained. By Mrs. Marcet. New Edition, revised and enlarged. Foolscap 8vo. 7*s.* 6*d.* cloth.

MARCET.—CONVERSATIONS ON VEGETABLE PHYSIOLOGY;
Comprehending the Elements of Botany, with their application to Agriculture. By Mrs. Marcet. New Edition. Foolscap 8vo. with Four Plates, 9*s.* cloth.

MARCET.—CONVERSATIONS ON LAND AND WATER.
By Mrs. Marcet. New Edition revised and corrected. Foolscap 8vo. with coloured Map shewing the comparative Altitude of Mountains, 5*s.* 6*d.* cloth.

MARGARET PERCIVAL.
By the Author of "Amy Herbert." Edited by the Rev. W. Sewell, B.D., Fellow and Tutor of Exeter College, Oxford. New Edition. 2 vols. foolscap 8vo. 12*s.* cloth.

MARRYAT.—BORNEO AND THE EAST INDIAN ARCHIPELAGO.
By Francis S. Marryat, late Midshipman of H.M.S. Samarang, Surveying Vessel. With many Drawings of Costume and Scenery, from Original Sketches made on the spot by Mr. Maryat. Imperial 8vo. with numerous Lithographic Plates and Wood Engravings, 31*s.* 6*d.* cloth.

MARRYAT (CAPT.)—MASTERMAN READY;
Or, the Wreck of the Pacific. Written for Young People. By Captain Marryat, C.B. author of "Peter Simple," etc. 3 vols. fcap. 8vo. with numerous Engravings on Wood, 22*s.* 6*d.* cloth.

MARRYAT.—THE PRIVATEER'S-MAN ONE HUNDRED YEARS AGO.
By Captain F. Marryat, C.B. author of "Peter Simple," "Masterman Ready," etc. 2 vols. fcap. 8vo. 12*s.* cloth.

MARRYAT.—THE MISSION;
Or, Scenes in Africa. Written for Young People. By Captain Marryat. C.B., author of "Peter Simple," "Masterman Ready," etc. 2 vols. fcap. 8vo. 12*s.* cloth.

MARRYAT.—THE SETTLERS IN CANADA.
Written for Young People. By Captain Marryat, C.B. author of "Peter Simple," "Masterman Ready," etc. New Edition. Fcap. 8vo. with two Illustrations, 7*s.* 6*d.* cloth.

MATTEUCCI.—LECTURES ON THE PHYSICAL PHŒNOMENA OF LIVING BEINGS. By Signor Carlo Matteucci, Professor of the University of Pisa. Translated under the superintendence of J. Pereira, M.D. F.R.S. Vice-President of the Royal Medical and Chirurgical Society. 12mo. 9*s.* cloth.

MAUNDER.—THE TREASURY OF KNOWLEDGE,

And LIBRARY of REFERENCE: a popular Compendium of Universal Knowledge. By Samuel Maunder. New Edition, revised throughout and enlarged. Foolscap 8vo. 10s. cloth; bound in roan, 12s.

*** The principal contents of the present new and thoroughly revised edition of "The Treasury of Knowledge," are—a new and enlarged English Dictionary, with a Grammar, Verbal Distinctions, and Exercises; a new Universal Gazetteer; a compendious Classical Dictionary; an Analysis of History and Chronology; a Dictionary of Law Terms; a new Synopsis of the British Peerage; and various useful tabular Addenda.*

MAUNDER.—THE SCIENTIFIC AND LITERARY TREASURY:

A New and Popular Encyclopædia of Science and the Belles Lettres; including all Branches of Science, and every Subject connected with Literature and Art. The whole written in a familiar style, adapted to the comprehension of all persons desirous of acquiring information on the subjects comprised in the work, and also adapted for a Manual of convenient Reference to the more instructed. By Samuel Maunder. New Edition. Fcap. 8vo. 10s. cloth; bound in roan, 12s.

MAUNDER.—THE BIOGRAPHICAL TREASURY:

Consisting of Memoirs, Sketches, and brief Notices of above 12,000 Eminent Persons of all Ages and Nations, from the Earliest Period of History; forming a new and complete Dictionary of Universal Biography. By Samuel Maunder. New Edition, revised throughout; with a copious Supplement. Foolscap 8vo. 10s. cloth; bound in roan, 12s.

MAUNDER.—THE TREASURY OF HISTORY;

Comprising a General Introductory Outline of Universal History, Ancient and Modern, and a Series of separate Histories of every principal Nation that exists; developing their Rise, Progress, and Present Condition, the Moral and Social Character of their respective Inhabitants, their Religion, Manners, and Customs, etc. etc. By Samuel Maunder. New Edit. Fcap. 8vo. 10s. cloth; bound in roan, 12s.

MAUNDER.—THE TREASURY OF NATURAL HISTORY;

Or, a Popular Dictionary of Animated Nature: in which Zoological Characteristics that distinguish the different Classes, Genera, and Species are combined with a variety of interesting Information illustrative of the Habits, Instincts, and General Economy of the Animal Kingdom. To which are added, a Syllabus of Practical Taxidermy, and a Glossarial Appendix. Embellished with Nine Hundred Engravings on Wood, from Drawings made expressly for this Work. By Samuel Maunder. Fcp. 8vo. with 900 Woodcuts, 10s. cloth; bound in roan, 12s.

MEMOIRS OF THE GEOLOGICAL SURVEY OF GREAT BRITAIN,

And of the Museum of Economic Geology in London. Published by order of the Lords Commissioners of Her Majesty's Treasury. Vol. I. Royal 8vo. with Woodcuts and 9 Plates, (seven coloured), 21s. cloth; and Vol. II. in two thick Parts, with 63 Plates (three coloured) and numerous Woodcuts, 42s. cloth, or, separately, 21s. each Part.

MILES (W.)—THE HORSE'S FOOT,

And How to Keep it Sound. By William Miles, Esq. New Edition, with an Appendix on Shoeing in General, and Hunters in Particular. Imperial 8vo. with Engravings, 9s. cloth.—The Appendix separately, price 2s. 6d.

*** Four casts or models of Shoes may be had; displaying the different kinds of Shoeing, price 3s. each; or 10s. 6d. the set.—No. 1. Shod for General Purposes.—No. 2. Shod for Hunting.—No. 3. Shod with Leather.—No. 4. Foot prepared for Shoeing.*

MILNER (REV. J. AND I.)—THE HISTORY OF THE CHURCH OF CHRIST. By the Rev. Joseph Milner, A.M. With Additions and Corrections by the late Rev. Isaac Milner, D.D. F.R.S. A New Edition, revised, with additional Notes, by the Rev. Thomas Grantham, B.D., Chaplain to the Bishop of Kildare. 4 vols. 8vo. 52s. cloth.

MIRACLES OF OUR SAVIOUR.

With rich and appropriate Borders of Original Design, a series of Illuminated Figures of the Apostles from the Old Masters, six Illuminated Miniatures, and other Embellishments. By the Illuminator of the "Parables." Square fcap. 8vo. in massive carved covers, 21s.; or bound in morocco, in the missal style, 30s.

MITCHELL.—JOURNAL OF AN EXPEDITION INTO THE INTERIOR OF TROPICAL AUSTRALIA, in Search of a Route from Sydney to the Gulf of Carpentaria. By Lieut.-Colonel Sir T. L. Mitchell, Knt. D.C.L. Surveyor-General of New South Wales, and late elective Member of the Legislative Council of that Colony. 8vo. with Maps, Views, and Engravings of Objects of Natural History, 21s. cloth.

MOHAN LAL.—LIFE OF THE AMIR DOST MOHAMMED KHAN OF KABUL: with his Political Proceedings towards the English, Russian, and Persian Governments, including the Victory and Disasters of the British Army in Affghanistan. By Mohan Lal, Esq., Knight of the Persian Order of the Lion and Sun; lately attached to the Mission in Kabul. 2 vols. 8vo. with numerous Portraits, 30*s.* cloth.

MONTGOMERY'S (JAMES) POETICAL WORKS.
New and only complete Edition. With some additional Poems, and Autobiographical Prefaces. Collected and edited by Mr. Montgomery. 4 vols. foolscap 8vo. with Portrait, and seven other Plates, 20*s.* cloth; bound in morocco, 1*l.* 16*s.*

MOORE'S POETICAL WORKS;
Containing the Author's recent Introduction and Notes. Complete in one volume, uniform with Lord Byron's Poems. Medium 8vo. with Portrait and Vignette, 1*l.* 1*s.* cloth; or 42*s.* bound in morocco, by Hayday.

*** Also, an Edition in 10 vols. foolscap 8vo. with Portrait, and 19 Plates, 2*l.* 10*s.* cloth; morocco, 4*l.* 10*s.*

MOORE'S LALLA ROOKH. AN ORIENTAL ROMANCE.
New Edition. Medium 8vo. illustrated with 13 fine Engravings, 21*s.* cloth; morocco, 35*s.*; with India Proof Plates, 42*s.* cloth.

MOORE'S LALLA ROOKH. AN ORIENTAL ROMANCE.
New Edition. Foolscap 8vo. with 4 Plates, by Westall, 10*s.* 6*d.* cloth; or 14*s.* bound in morocco.

MOORE'S IRISH MELODIES.
Illustrated by D. Maclise, R.A. Imp. 8vo. with 161 Designs, engraved on Steel, 3*l.* 3*s.* boards; or 4*l.* 14*s.* 6*d.* bound in morrocco, by Hayday. Proof Impressions (only 200 copies printed, of which a few remain), 6*l.* 6*s.* boards.

*** *India Proofs before letters of the* 161 *Designs, on Quarter Colombier, in Portfolio (only* 25 *copies printed, of which a few remain),* 31*l.* 10*s.*

India Proofs before letters of the 51 *large Designs, on Quarter Colombier, in Portfolio (only* 25 *copies printed, of which a few remain),* 18*l.* 18*s.*

MOORE'S IRISH MELODIES.
New Edition. Fcap. 8vo. with Vignette Title, 10*s.* cloth; bound in morocco, 13*s.* 6*d.*

MOORE.—THE POWER OF THE SOUL OVER THE BODY,
Considered in relation to Health and Morals. By George Moore, M.D. Member of the Royal College of Physicians, London, etc. New Edition. Post 8vo. 7*s.* 6*d.* cloth.

MOORE.—THE USE OF THE BODY IN RELATION TO THE MIND.
By George Moore, M.D. Member of the Royal College of Physicians, London, etc. New Edition. Post 8vo. 9*s.* cloth.

MOORE.—MAN AND HIS MOTIVES.
By George Moore, M.D. Member of the Royal College of Physicians, London, etc.; author of "The Power of the Soul over the Body," and "The Use of the Body in relation to the Mind." Post 8vo. 8*s.* cloth.

MORAL OF FLOWERS (THE).
New Edition. Royal 8vo. with 24 beautifully coloured Engravings, 1*l.* 10*s.* half-bound.

MOSELEY.—ILLUSTRATIONS OF PRACTICAL MECHANICS.
By the Rev. H. Moseley, M.A., Professor of Natural Philosophy and Astronomy in King's College, London; author of "The Mechanical Principles of Engineering and Architecture." New Edition. Fcap. 8vo. with Woodcuts, 8*s.* cloth.

MOSELEY.—THE MECHANICAL PRINCIPLES OF ENGINEERING AND ARCHITECTURE. By the Rev. H. Moseley, M.A. F.R.S., Professor of Natural Philosophy and Astronomy in King's College, London; and author of "Illustrations of Practical Mechanics," etc. 8vo. with Woodcuts and Diagrams, 1*l.* 4*s.* cloth.

MOSHEIM'S ECCLESIASTICAL HISTORY,
Ancient and Modern. Translated, with copious Notes, by James Murdock, D.D. New Edition, revised, and continued, by the Rev. Henry Soames, M.A. 4 vols. 8vo. 48*s.* cloth.

MURRAY.—AN ENCYCLOPÆDIA OF GEOGRAPHY;

comprising a complete Description of the Earth: exhibiting its Relation to the Heavenly Bodies, its Physical Structure, the Natural History of each Country, and the Industry, Commerce, Political Institutions, and Civil and Social State of all Nations. By Hugh Murray, F.R.S.E. New Edition. 8vo. with 82 Maps, and upwards of 1,000 other Wood Engravings, 3*l.* cloth.

NECKER DE SAUSSURE.—PROGRESSIVE EDUCATION;

Or, Considerations on the Course of Life. Translated and Abridged from the French of Madame Necker De Saussure, by Miss Holland. 3 vols. foolscap 8vo. 19*s.* 6*d.* cloth.

*** *Separately—vols.* I. *and* II. 12*s.*; *vol.* III. 7*s.* 6*d.*

OWEN.—LECTURES ON THE COMPARATIVE ANATOMY AND PHYSIOLOGY OF THE INVERTEBRATE ANIMALS,

delivered at the Royal College of Surgeons in 1843. By Richard Owen, F.R.S. Hunterian Professor to the College. From Notes taken by William White Cooper, M.R.C.S. and revised by Professor Owen. With Glossary and Index. 8vo. with nearly 140 Woodcuts, 14*s.* cloth.

OWEN.—LECTURES ON THE COMPARATIVE ANATOMY AND PHYSIOLOGY of the VERTEBRATE ANIMALS,

delivered at the Royal College of Surgeons in 1844 and 1846. By Richard Owen, F.R.S. Hunterian Professor to the College. In 2 vols. Vol. I. 8vo. with numerous Woodcuts, 14*s.* cloth.

PARABLES OF OUR LORD.

Richly Illuminated with appropriate Borders, printed in Colours, and in Black and Gold; with a Design from one of the early German engravers. Square foolscap 8vo., uniform in size with the "Sermon on the Mount," 21*s.*, in a massive carved binding; morocco, 30*s.*, bound by Hayday.

PARKES.—DOMESTIC DUTIES;

Or, Instructions to Young Married Ladies on the Management of their Households and the Regulation of their Conduct in the various Relations and Duties of Married Life. By Mrs. W. Parkes. New Edition. Foolscap 8vo. 9*s.* cloth.

PARNELL.—A TREATISE ON ROADS,

Wherein the Principles on which Roads should be made are explained and illustrated by the Plans, Specifications, and Contracts, made use of by Thomas Telford, Esq., on the Holyhead Road. By the Rt. Hon. Sir Henry Parnell, Bart. New Edition, enlarged. 8vo. with Nine Plates, 21*s.* cloth.

PARROT.—THE ASCENT OF MOUNT ARARAT.

By Dr. Friedrich Parrot, Professor of Natural Philosophy in the University of Dorpat, Russian Imperial Councillor of State, etc. Translated and Edited by W. D. Cooley, Esq. author of the "History of Maritime and Inland Discovery," etc. 8vo. with a Map by Arrowsmith, and Woodcuts, 14*s.* cloth.

PEREIRA.—A TREATISE ON FOOD AND DIET:

With Observations on the Dietetical Regimen suited for Disordered States of the Digestive Organs; and an Account of the Dietaries of some of the principal Metropolitan and other Establishments for Paupers, Lunatics, Criminals, Children, the Sick, etc. By Jon. Pereira, M.D. F.R.S., author of "Elements of Materia Medica." 8vo. 16*s.* cloth.

PERICLES:

A Tale of Athens in the 83d Olympiad. By the Author of "A Brief Sketch of Greek Philosophy." 2 vols. post 8vo. 18*s.* cloth.

PESCHEL (C. F.)—ELEMENTS OF PHYSICS,

By C. F. Peschel, Principal of the Royal Military College, Dresden, etc. etc. Translated from the German, with Notes, by E. West. 3 vols. fcap. 8vo. with Woodcuts, 21*s.* cloth.

Separately { Part I. The Physics of Ponderable Bodies. Fcap. 8vo. 7*s.* 6*d.* cloth.
Part II. Imponderable Bodies (Light, Heat, Magnetism, Electricity, and Electro-Dynamics). 2 vols. fcap. 8vo. 13*s.* 6*d.* cloth.

PHILLIPS.—FIGURES & DESCRIPTIONS OF THE PALÆOZOIC FOSSILS OF CORNWALL, DEVON, and WEST SOMERSET;

observed in the course of the Ordnance Geological Survey of that District. By John Phillips, F.R.S. F.G.S. etc. Published by Order of the Lords Commissioners of H. M. Treasury. 8vo. with 60 Plates, comprising very numerous Figures, 9*s.* cloth.

PHILLIPS.—AN ELEMENTARY INTRODUCTION TO MINERALOGY;
Comprising a Notice of the Characters, Properties, and Chemical Constitution of Minerals: with Accounts of the Places and Circumstances in which they are found. By William Phillips, F.L.S. M.G.S. etc. A New Edition, corrected, enlarged, and improved, by W. H. Miller, M.A. F.R.S. Professor of Mineralogy in the University of Cambridge. 8vo. with numerous Wood Engravings. [*In the press.*

PITMAN (THE REV. J. R.)—SERMONS
On the principal Subjects comprised in the Book of Psalms, abridged from Eminent Divines of the Established Church. By the Rev. J. R. Pitman, A.M. Domestic Chaplain to Her Royal Highness the Duchess of Kent. 8vo. 14*s.* cloth.

PLUNKETT.—THE PAST AND FUTURE OF THE BRITISH NAVY.
By Captain the Hon. E. Plunkett, R.N. 2d Edition, corrected and enlarged; with Notes, and New Information communicated by several Officers of Distinction. Post 8vo. 8*s.* 6*d.* cloth.

THE POCKET AND THE STUD;
Or, How to procure and keep Horses, with some regard to obtaining the Animal required, and to keeping him without emptying the Pocket. Being the result of many years' experience of "Harry Hieover." Foolscap 8vo. with a Portrait of "One of the Stud," from a Sketch by "Harry Hieover." [*Nearly ready.*

POETS' PLEASAUNCE (THE);
Or, Garden of all Sorts of Pleasant Flowers, which our Pleasant Poets have in Past Time (for Pastime) Planted. By Eden Warwick. Square crown 8vo. with Twenty nine Ornamental Borders composed of Flowers and Insects, engraved on Wood, 30*s.* boards; or 45*s.* bound in morocco, by Hayday.

PORTLOCK.—REPORT ON THE GEOLOGY OF THE COUNTY OF LONDONDERRY, and of Parts of Tyrone and Fermanagh, examined and described under the Authority of the Master-General and Board of Ordnance. By J. E. Portlock, F.R.S. etc. 8vo. with 48 Plates, 24*s.* cloth.

PYCROFT.—A COURSE OF ENGLISH READING;
Adapted to every Taste and Capacity. With Anecdotes of Men of Genius. By the Rev. James Pycroft, B.A., author of "Greek Grammar Practice," and "Latin Grammar Practice;" Editor of "Virgil, with Marginal References." Foolscap 8vo. 6*s.* 6*d.* cloth.

RANKE (PROFESSOR).—RANKE'S HISTORY OF THE REFORMATION.
Translated by Sarah Austin, translator of Ranke's "History of the Popes." Vols. I. and II. 8vo. 30*s.*; Vol. III. 18*s.* cloth.

READER (THOMAS).—TIME TABLES.
On a New and Simplified Plan; to facilitate the Operation of Discounting Bills, and the Calculation of Interest on Banking and Current Accounts, etc.; shewing, without calculation, the Number of Days from every Day in the Year to any other Day, for any Period not exceeding 365 Days. By Thomas Reader. Post 8vo. 14*s.* cloth, or 17*s.* calf lettered.

REID (DR.)—ILLUSTRATIONS OF THE THEORY AND PRACTICE OF VENTILATION: with Remarks on Warming, Exclusive Lighting, and the Communication of Sound. By D. B. Reid, M.D. F.R.S.E. etc. 8vo. with Engravings on Wood, 16*s.* cloth.

RENAUD.—MATUTINA:
Morning Readings, chiefly Practical, selected and original. Adapted to the use of the Younger Members of the Church of England. By the Rev. George Renaud, M.A. late Fellow of C. C. C. Oxford. Fcap. 8vo. 5*s.* cloth.

REPTON.—THE LANDSCAPE GARDENING & LANDSCAPE ARCHITECTURE of the late Humphrey Repton, Esq.; being his entire Works on these subjects. A New Edition, with an Historical and Scientific Introduction, a systematic Analysis, a Biographical Notice, Notes, and a copious Alphabetical Index. By J. C. Loudon, F.L.S., etc. 8vo. with a Portrait and upwards of 250 Engravings, 30*s.* cloth; with coloured Plates, 3*l.* 6*s.* cloth.

REST IN THE CHURCH.
By the Author of "From Oxford to Rome; and, How it Fared with Some who lately made the Journey." New Edition. Fcap. 8vo. 6*s.* 6*d.* cloth.

RICH.—AN ILLUSTRATED COMPANION TO THE LATIN DICTIONARY;
Being a Dictionary of all the Words respecting Visible Objects connected with the Arts, Science, and Every-day Life of the Ancients. Illustrated by about Two Thousand Engravings on Wood, from the Antique. By Anthony Rich, jun. B.A. late of Caius College, Cambridge; and one of the contributors to Dr. Smith's "Dictionary of Greek and Roman Antiquities." Post 8vo. with 2,000 Woodcuts, 18*s.* cloth.

RICHTER.—LEVANA; OR, THE DOCTRINE OF EDUCATION.
Translated from the German of Jean Paul Fr. Richter. Post 8vo. 10s. 6d. cloth.

RIDDLE.—A COMPLETE ENGLISH-LATIN AND LATIN-ENGLISH DICTIONARY, from the best sources, chiefly German. By the Rev. J. E. Riddle, M.A. New Edition. 8vo. 31s. 6d. cloth.

*** Separately—The English-Latin Dictionary, 10s. 6d.; the Latin-English Dictionary, 21s.

RIDDLE.—A DIAMOND LATIN-ENGLISH DICTIONARY,
A Guide to the Meaning, Quality, and right Accentuation of Latin Classical Words. By the Rev. J. E. Riddle, M.A. New Edition. Royal 32mo. 4s. bound.

RIDDLE.—LETTERS FROM AN ABSENT GODFATHER;
Or, a Compendium of Religious Instruction for Young Persons. By the Rev. J. E. Riddle, M.A. Foolscap 8vo. 6s. cloth.

RIDDLE.—ECCLESIASTICAL CHRONOLOGY;
Or, Annals of the Christian Church, from its Foundation to the present Time. Containing a View of General Church History, and the Course of Secular Events; the Limits of the Church and its Relations to the State; Controversies; Sects and Parties; Rites, Institutions, and Discipline; Ecclesiastical Writers, etc. By the Rev. J. E. Riddle, M.A. 8vo. 15s. cloth.

RITCHIE (ROBERT.)—RAILWAYS: THEIR RISE AND PROGRESS, AND CONSTRUCTION, with Remarks on Railway Accidents, and Proposals for their Prevention. By Robert Ritchie, Esq., F.R.S., S.A., Civil Engineer, Associate of the Institution of Civil Engineers, etc. Fcap. 8vo. with Woodcuts and Diagrams, 9s. cloth.

RIVERS.—THE ROSE AMATEUR'S GUIDE:
Containing ample Descriptions of all the fine leading varieties of Roses, regularly classed in their respective Families; their History and Mode of Culture. By T. Rivers, Jun. Fourth Edition, corrected and improved. Foolscap 8vo. 6s. cloth.

ROBINSON.—THE WHOLE ART OF MAKING BRITISH WINES, CORDIALS, AND LIQUEURS, IN THE GREATEST PERFECTION; AS ALSO STRONG AND CORDIAL WATERS. To which is added, a Collection of Valuable Recipes for Brewing Fine and Strong Ales, and Miscellaneous Articles connected with the Practice. By James Robinson. Fcap. 8vo. 6s. cloth.

ROBINSON (JAMES).—THE WHOLE ART OF CURING, PICKLING, and SMOKING MEAT and FISH, both in the British and Foreign Modes. With many useful Miscellaneous Recipes, and full Directions for the Construction of an Economical Drying-Chimney and Apparatus, on an entirely new Plan. By James Robinson, Eighteen Years a Practical Curer. Fcap. 8vo. 4s. 6d. cloth.

ROGERS.—THE VEGETABLE CULTIVATOR;
Containing a plain and accurate Description of all the different Species of Culinary Vegetables, with the most approved Method of Cultivating them by Natural and Artificial Means, and the best Modes of Cooking them. By John Rogers, author of "The Fruit Cultivator." New Edition. Foolscap 8vo. 7s. cloth.

ROGET.—THE ECONOMIC CHESS-BOARD;
Being a Chess-Board, provided with a complete set of Chess-Men, for playing Games in carriages, or out of doors, and for folding up, and carrying in the pocket, without disturbing the Game. Invented by P. M. Roget, M.D. and registered according to Act of Parliament. New Edition. In a neat fcap. 8vo. case, price 2s. 6d.

ROWTON.—THE FEMALE POETS OF GREAT BRITAIN,
Chronologically arranged: with copious Selections, and Critical Remarks. By Frederic Rowton, author of "The Debater," etc. Square crown 8vo. 14s. cloth.

ROWTON (F.)—THE DEBATER;
Being a Series of complete Debates, Outlines of Debates, and Questions for Discussion. With ample references to the best sources of information upon each particular topic. By Frederic Rowton, Lecturer on General Literature. Foolscap 8vo. 6s. cloth.

SANDBY.—MESMERISM AND ITS OPPONENTS.
By George Sandby, M.A. Vicar of Flixton, Suffolk. Second Edition, considerably enlarged; with an Introductory Chapter on the Hostility of Scientific and Medical Men to Mesmerism. 16mo. 5s. cloth; or in two Parts, 2s. each, sewed.

SANDFORD (REV. JOHN).—PAROCHIALIA,
or Church, School, and Parish. By the Rev. John Sandford, B.D. Vicar of Dunchurch, Chaplain to the Lord Bishop of Worcester, Hon. Canon of Worcester, and Rural Dean. 8vo. with numerous Woodcuts, 16s. cloth.

SANDFORD.—WOMAN IN HER SOCIAL AND DOMESTIC CHARACTER.
By Mrs. John Sandford. 6th Edition. Foolscap 8vo. 6*s.* cloth.

SANDFORD.—FEMALE IMPROVEMENT.
By Mrs. John Sandford. New Edition. Foolscap 8vo. 7*s.* cloth.

SCHOMBURGK.—THE HISTORY OF BARBADOS:
Comprising a Geographical and Statistical Description of the Island; a Sketch of the Historical Events since the Settlement; and an Account of its Geology and Natural Productions. By Sir Robert H. Schomburgk, Ph.D. K.R.E. etc. Royal 8vo. with Chart, Views, and Engravings, 31*s.* 6*d.* cloth.

SCHOMBURGK.—A TOPOGRAPHICAL MAP OF THE ISLAND OF BARBADOS, based upon Mayo's Original Survey in 1721, and corrected to the year 1846. By Sir Robert H. Schomburgk, Ph.D. K.R.E. Engraved by Arrowsmith, on 2 large sheets, 21*s.* coloured.

SCHOPENHAUER.—YOUTHFUL LIFE AND PICTURES OF TRAVEL:
Being the Autobiography of Madame Schopenhauer. Translated from the German. 2 vols. foolscap 8vo. 12*s.* boards.

SEAWARD.—SIR EDWARD SEAWARD'S NARRATIVE OF HIS SHIPWRECK,
and consequent Discovery of certain Islands in the Caribbean Sea: with a Detail of many extraordinary and highly interesting Events in his Life, from 1733 to 1749, as written in his own Diary. Edited by Miss Jane Porter. New Edition. 2 vols. post 8vo. 21*s.* cloth.

SELECT WORKS OF THE BRITISH POETS:
From Chaucer to Withers. With Biographical Sketches, by R. Southey, LL.D. Medium 8vo. 30*s.* cloth; or, with gilt edges, 31*s.* 6*d.*

SELECT WORKS OF THE BRITISH POETS:
From Ben Jonson to Coleridge. With Biographical and Critical Prefaces by Dr. Aikin. A New Edition, with additional Selections, from more recent Poets, by Lucy Aikin. Medium 8vo. 18*s.* cloth.

*** *The peculiar feature of these two works is, that the Poems included are printed entire without mutilation or abridgment.*

THE SERMON ON THE MOUNT.
Intended as a Birthday-Present, or Gift-Book for all Seasons. Printed in Gold and Colours, in the Missal Style; with Ornamental Borders by Owen Jones, Architect, and an Illuminated Frontispiece by W. Boxall, Esq. A new edition. Foolscap 4to. in a rich brocaded silk cover, 21*s.*; or bound in morocco, by Hayday, 25*s.*

SHAKSPEARE, BY BOWDLER.
THE FAMILY SHAKSPEARE, in which nothing is added to the Original Text; but those Words and Expressions are omitted which cannot with propriety be read aloud. By T. Bowdler, Esq. F.R.S. New Edition. 8vo. with 36 Illustrations after Smirke, etc., 21*s.* cloth; or, without Illustrations, 8 vols. 8vo. 4*l.* 14*s.* 6*d.* boards.

SHORT WHIST:
Its Rise, Progress, and Laws; with the recent Decisions of the Clubs, and Observations to make any one a Whist Player. Containing also the Laws of Piquet, Cassino, Ecarte, Cribbage, Backgammon. By Major A * * * * * New Edition. To which are added, Precepts for Tyros. By Mrs. B * * * * * Foolscap 8vo. 3*s.* cloth, gilt edges.

THE GOOD SHUNAMMITE.
From the Scriptures—2 Kings, chap. IV. 8 to 37. With Six Original Designs by A. Klein, and an Ornamental Border to each page, in the Missal style, by L. Gruner. Printed in Colours and Gold. Square fcap. 8vo, uniform in size with "Miracles of our Lord," 21*s.* in massive carved covers; or 30*s.* bound in morocco, in the Missal style.

SINCLAIR.—THE BUSINESS OF LIFE.
By Catherine Sinclair, author of "The Journey of Life," "Jane Bouverie," "Modern Accomplishments," "Modern Society," etc. 2 vols. fcap. 8vo. 10*s.* cloth.

"The book, without being of a directly devotional character, or belonging to the class of light reading, combines several of the best qualities of both, and makes general literature and entertaining anecdote serve as handmaids to religious instruction. We have seen many pompous treatises containing not half the talent or a tithe of the knowledge compressed into these unpretending little volumes."—Britannia.

SINCLAIR.—THE JOURNEY OF LIFE.

By Catherine Sinclair, author of "The Business of Life," "Modern Society," "Jane Bouverie," etc. New Edition, corrected and enlarged. Fcap. 8vo. 5s. cloth.

SINNETT.—BY-WAYS OF HISTORY, FROM THE TWELFTH TO THE SIXTEENTH CENTURY. By Mrs. Percy Sinnett. 2 vols. post 8vo. 18s. cloth.

THE SKETCHES;

Three Tales. By the Authors of "Amy Herbert," "The King's Messengers," and "Hawkstone." New Edition. Fcap. 8vo. with six Plates, 8s. cloth.

SMITH.—SACRED ANNALS:

Or, Researches into the History and Religion of Mankind, from the Creation of the World to the Death of Isaac: deduced from the Writings of Moses and other Inspired Authors, copiously illustrated and confirmed by the ancient Records, Traditions, and Mythology of the Heathen World. By George Smith, F.S.A. etc. author of "The Religion of Ancient Britain," etc. Crown 8vo. 10s. cloth.

SMITH (GEORGE).—THE RELIGION OF ANCIENT BRITAIN HISTORICALLY CONSIDERED: Or, a Succinct Account of the several Religious Systems which have obtained in this Island from the Earliest Times to the Norman Conquest: including an Investigation into the Early Progress of Error in the Christian Church, the Introduction of the Gospel into Britain, and the State of Religion in England till Popery had gained the Ascendancy. By George Smith, F.A.S. New Edition. 8vo. 7s. 6d. cloth.

SMITH (GEORGE).—PERILOUS TIMES:

Or, the Agressions of Anti-Christian Error on Scriptural Christianity: considered in reference to the Dangers and Duties of Protestants. By George Smith, F.A.S. Member of the Royal Asiatic Society, and of the Royal Society of Literature. Foolscap 8vo. 6s. cloth.

SMITH (JAMES).—THE VOYAGE AND SHIPWRECK OF SAINT PAUL:

with Dissertations on the Sources of the Writings of St. Luke, and the Ships and Navigation of the Antients. By James Smith, Esq. of Jordanhill, F.R.S. etc. 8vo. with illustrative Views, Charts, and Woodcuts, 14s. cloth.

SMITH.—AN INTRODUCTION TO THE STUDY OF BOTANY.

By Sir J. E. Smith, late President of the Linnæan Society. 7th Edition, corrected; in which the object of Smith's "Grammar of Botany" is combined with that of the "Introduction." By Sir William Jackson Hooker, K.H. LL.D. etc. 8vo. with 36 Steel Plates, 16s. cloth; with coloured Plates, 2l. 12s. 6d. cloth.

SMITH.—COMPENDIUM OF THE ENGLISH FLORA.

By Sir J. E. Smith. New Edition, with Additions and Corrections. By Sir W. J. Hooker. 12mo. 7s. 6d. cloth.

THE SAME IN LATIN. New Edition. 12mo. 7s. 6d.

SMITH.—THE ENGLISH FLORA.

By Sir James Edward Smith, M.D. F.R.S., late President of the Linnæan Society, etc. 6 vols. 8vo. 3l. 12s. boards.

SMITH (SYDNEY).—SERMONS PREACHED AT ST. PAUL'S CATHEDRAL, the Foundling Hospital, and several Churches in London; together with others addressed to a Country Congregation. By the late Rev. Sydney Smith, Canon Residentiary of St. Paul's Cathedral. 8vo. 12s. cloth.

SMITH.—THE WORKS OF THE REV. SYDNEY SMITH.

New Edition, with Additions. 3 vols. 8vo. with Portrait, 36s. cloth.

SOAMES.—THE LATIN CHURCH DURING ANGLO-SAXON TIMES.

By the Rev. Henry Soames, M.A., Editor of "Mosheim's Institutes of Ecclesiastical History." 8vo. 14s. cloth.

SOME PASSAGES FROM MODERN HISTORY.

By the Author of "Letters to My Unknown Friends," and "Twelve Years Ago." Foolscap 8vo. 6s. 6d. cloth.

SOPHOCLES, BY LINWOOD.

SOPHOCLIS TRAGŒDIÆ SUPERSTITES. Recensuit, et brevi adnotatione instruxit Gulielmus Linwood, A.M. Ædis Christi apud Oxonienses Alumnus. 8vo. 16s. cloth.

SOUTHEY (ROBERT).—THE LATE MR. SOUTHEY'S COMMON-PLACE BOOK; comprising his Readings and Collections in History, Biography, Manners and Literature, Voyages and Travels, etc. etc. [*In the press.*

SOUTHEY (ROBERT).—THE DOCTOR, ETC.
By the late Robert Southey. A New Edition, complete in One Volume. Edited by the Author's Son-in-Law, the Rev. John Wood Warter. Square crown 8vo., with Portrait, Vignette Title-page, and Bust of the Author, 21*s.* cloth.

SOUTHEY.—THE LIFE OF WESLEY,
And Rise and Progress of Methodism. By Robert Southey, Esq. LL.D. New Edition, with Notes by the late Samuel Taylor Coleridge, Esq., and Remarks on the Life and Character of John Wesley, by the late Alexander Knox, Esq. Edited by the Rev. Charles Cuthbert Southey, A.M. Curate of Cockermouth. 2 vols. 8vo. with two Portraits, 1*l.* 8*s.* cloth.

SOUTHEY'S (ROBERT) COMPLETE POETICAL WORKS:
Containing all the Author's last Introductions and Notes. Complete in One Volume, 24*s.* 6*d.*, with Portrait and Vignette, uniform with Byron's and Moore's Poetical Works. Medium 8vo. 21*s.* cloth; or 42*s.* bound in morocco, by Hayday.

Also, an Edition in 10 vols. foolscap 8vo. with Portrait and 19 Plates, 2*l.* 10*s.*; morocco, 4*l.* 10*s.*

SPIRIT OF THE WOODS (THE).
By the Author of "The Moral of Flowers." New Edition. Royal 8vo. with 23 beautifully coloured Engravings of the Forest Trees of Great Britain, 1*l.* 11*s.* 6*d.* cloth.

STABLE TALK AND TABLE TALK; OR, SPECTACLES FOR YOUNG SPORTSMEN. By Harry Hieover. 2 vols. 8vo. with Portrait, 24*s.* cloth.

STEEL'S SHIPMASTER'S ASSISTANT.
Compiled for the use of Merchants, Owners and Masters of Ships, Officers of Customs, and all Persons connected with Shipping or Commerce; containing the Law and Local Regulations affecting the Ownership, Charge, and Management of Ships and their Cargoes; together with Notices of other Matters, and all necessary Information for Mariners. New Edition, rewritten throughout. Edited by Graham Willmore, Esq. M.A. Barrister-at-Law; George Clements, of the Customs, London, and William Tate, author of "The Modern Cambist." 8vo. 28*s.* cloth; or 29*s.* bound.

STEPHEN.—THE HISTORY OF THE CHURCH OF SCOTLAND,
From the Reformation to the Present Time. By Thomas Stephen, author of "The Book of the Constitution," "Spirit of the Church of Rome," etc. 4 vols. 8vo. with 24 highly-finished Portraits, engraved on Steel, 32*s.* cloth.

STEPHENS.—A MANUAL OF BRITISH COLEOPTERA;
Or, BEETLES: containing a Description of all the Species of Beetles hitherto ascertained to inhabit Great Britain and Ireland, etc. By J. F. Stephens, F.L.S. Post 8vo. 14*s.* cloth.

STEWART.—THE MEANS OF FACILITATING THE TRANSFER OF LAND:
In Three Lectures. By James Stewart, Esq., of Lincoln's Inn, Barrister. 8vo. 5*s.* cloth.

THE SUITOR'S INSTRUCTOR IN THE PRACTICE OF THE COUNTY COURTS: containing all the Information necessary for Conducting or Defending a Suit; the Fees payable on each Step; Definitions of the Legal Terms used in the Proceedings; an Abstract of the Act of Parliament; the Rules of Practice, etc. etc. Also a District Directory, giving the Names of all the Streets (and the number of Houses in each Street) which form the Boundaries of the Metropolitan Districts; made from an actual Perambulation around each: and a List of the Country Districts. By a County Court Assistant Clerk. 12mo. 4*s.* 6*d.* cloth.

SUMMERLY.—THE SEA AND THE RAILWAY:
Their new Relations set forth in a Jaunt along the Manchester, Sheffield, and Lincolnshire Railway to Grimsby Docks, by Felix Summerly. With Woodcuts by C. W. Cope, A.R.A.; D. Cox, jun.; T. Creswick, A.R.A.; and R. Redgrave, A.R.A. [*Nearly ready.*

SYMONDS.—THE LAW RELATING TO MERCHANT SEAMEN,
Arranged chiefly for the use of Masters and Officers in the Merchant Service. With an Appendix, containing the Act 7 & 8 Vic. c. 112; the Regulations under which Lascars may be employed; and some forms of Proceedings before Magistrates. By E. W. Symonds, Esq. Chief Clerk of the Thames Police Court. Third Edition. 12mo. 5*s.* cloth.

TATE.—THE CONTINUOUS HISTORY OF THE LIFE AND WRITINGS OF ST. PAUL, on the basis of the Acts; with Intercalary Matter of Sacred Narrative, supplied from the Epistles, and elucidated in occasional Dissertations: with the Horæ Paulinæ of Dr. Paley, in a more correct edition, subjoined. By James Tate, M.A. 8vo. Map, 13*s.* cloth.

TAYLER (REV. CHARLES B.)—MARGARET;
Or, the Pearl. By the Rev. Charles B. Tayler, M.A. Rector of St. Peter's, Chester, author of "Lady Mary; or, Not of the World;" etc. New Edition. Foolscap 8vo. 6s. cloth.

TAYLER (REV. CHARLES B.)—LADY MARY; OR, NOT OF THE WORLD.
By the Rev. Charles B. Tayler, Rector of St. Peter's, Chester; author of "Margaret, or the Pearl," etc. New Edition. Foolscap 8vo. with a Frontispiece engraved by J. Absolon, 6s. 6d. cloth.

TAYLOR.—LOYOLA AND JESUITISM.
By Isaac Taylor. Post 8vo. [*In the Autumn.*

TAYLOR (JEREMY).—BISHOP JEREMY TAYLOR'S ENTIRE WORKS:
With the Life of Bishop Heber. Revised and corrected by the Rev. Charles Page Eden, Fellow of Oriel College, Oxford. Vol. II. (the first in the order of publication) contains the Life of Christ; Vol. III. the Holy Living and Dying; Vol. IV. a Course of Sermons for all the Sundays of the Year. 8vo. 10s. 6d. each, cloth.

*** To be completed in Ten Volumes, price 10s. 6d. each. Vol. V. containing the* Episcopacy, etc. *is nearly ready.*

THIRLWALL.—THE HISTORY OF GREECE.
By the Right Rev. the Lord Bishop of St. David's. A new Edition, revised; with Notes. Vols. I. to IV. demy 8vo. with Maps, 12s. each cloth. To be completed in 8 volumes.
[Vol. V. *is nearly ready.*

*** Also, an Edition in 8 vols. fcap. 8vo. with Vignette Titles, 2l. 8s. cloth.*

THOMSON'S SEASONS.
Edited, with Notes, Philosophical, Classical, Historical, and Biographical, by Anthony Todd Thomson, M.D. F.L.S., Professor of Materia Medica and Therapeutics, and of Forensic Medicine, in University College, London, etc. Fcap. 8vo. 7s. 6d. cloth.

THOMSON'S SEASONS.
Edited by Bolton Corney, Esq. Illustrated with Seventy-seven Designs drawn on Wood by the Members of the Etching Club. Engraved by Thompson and other eminent Engravers. Square crown 8vo. uniform with "Goldsmith's Poems," 21s. cloth; bound in morocco, by Hayday, 36s.

THOMSON.—EXPERIMENTAL RESEARCHES ON THE FOOD OF ANIMALS, AND THE FATTENING OF CATTLE: with Remarks on the Food of Man. By Robert Dundas Thomson, M.D. of the University of Glasgow. Fcap. 8vo. 5s. cloth.

"The question of the origin of the fat of animals appears to be completely resolved by these beautiful and elaborate experiments."—Baron Liebig.

THOMSON (JOHN).—TABLES OF INTEREST,
At Three, Four, Four-and-a-half, and Five per Cent., from One Pound to Ten Thousand, and from One to Three Hundred and Sixty-five Days, in a regular progression of Single Days; with Interest at all the above Rates, from One to Twelve Months, and from One to Ten Years. Also, Tables shewing the Exchange on Bills, etc. etc. etc. By John Thomson, Accountant. New Edition. 12mo. 8s. bound.

THOMSON.—THE DOMESTIC MANAGEMENT OF THE SICK ROOM,
Necessary, in Aid of Medical Treatment, for the Cure of Diseases. By Anthony Todd Thomson, M.D. F.L.S. etc. New Edition. Post 8vo. 10s. 6d. cloth.

TISCHENDORFF.—TRAVELS IN THE EAST.
By Constantine Tischendorff, Editor of the "Codex Ephræmi Rescriptus," "Codex Friderico-Augustanus," etc. Translated from the German by W. E. Shuckard. 16mo. 6s. 6d. cloth.

TOMLINE (BISHOP).—AN INTRODUCTION TO THE STUDY OF THE BIBLE:
Being the First Volume of the Elements of Christian Theology; containing Proofs of the Authenticity and Inspiration of the Holy Scriptures; a Summary of the History of the Jews; an Account of the Jewish Sects; and a brief Statement of the Contents of the several Books of the Old Testament. By the late George Tomline, D.D. F.R.S. New Edition. Foolscap 8vo. 5s. 6d. cloth.

TOOKE.—THE HISTORY OF PRICES;
With reference to the Causes of their principal Variations, from 1792 to the Present Time. Preceded by a Sketch of the History of the Corn Trade in the last Two Centuries. By Thomas Tooke, Esq. F.R.S. 3 vols. 8vo. 2l. 8s. cloth.

TOOKE.—THE HISTORY OF PRICES,
And of the State of the Circulation, from 1839 to 1847, inclusive: with a General Review of the Currency Question, and Remarks on the Operation of the Act 7 and 8 Vict. c. 32: being a continuation of "The History of Prices from 1792 to 1839." By Thomas Tooke, Esq. F.R.S. 8vo. 18s. cloth.

TOPHAM.—CHEMISTRY MADE EASY,
For the Use of Agriculturists. By John Topham, A.M. Rector of St. Andrew, St.-Mary Witton, and St. Nicholas, Droitwich. New Edition. 16mo. 2*s.* sewed.

TOWNSEND (CHARLES).—THE LIVES OF TWELVE EMINENT JUDGES
OF THE LAST AND OF THE PRESENT CENTURY. By W. Charles Townsend, Esq., A.M. Recorder of Macclesfield, author of "Memoirs of the House of Commons." 2 vols. 8vo. 28*s.* cloth.

TURNER.—THE SACRED HISTORY OF THE WORLD,
Attempted to be Philosophically considered, in a Series of Letters to a Son. By Sharon Turner, F.S.A. and R.A.S.L. Eighth Edition, edited by the Rev. Sydney Turner. 3 vols. post 8vo. 31*s.* 6*d.* cloth.

TURNER.—THE HISTORY OF ENGLAND,
From the Earliest Period to the Death of Elizabeth. By Sharon Turner, Esq. F.A.S. R.A.S.L. New Editions. 12 vols. 8vo. 8*l.* 8*s.* cloth; or, separately—

THE HISTORY of the ANGLO-SAXONS. 3 vols. 8vo. 2*l.* 5*s.*

THE HISTORY of ENGLAND during the MIDDLE AGES. 5 vols. 8vo. 3*l.*

THE HISTORY of the REIGN of HENRY VIII. 2 vols. 8vo. 26*s.*

THE REIGNS of EDWARD VI., MARY, and ELIZABETH. 2 vols. 8vo. 32*s.*

TURTON'S (DR.) MANUAL OF THE LAND AND FRESHWATER SHELLS OF
THE BRITISH ISLANDS. A new Edition, thoroughly revised, with Additions. By John Edward Gray. Post 8vo. with Woodcuts, and 12 coloured Plates, 15*s.* cloth.

TWELVE YEARS AGO:
A Tale. By the Author of "Letters to My Unknown Friends." Foolscap 8vo. 6*s.* 6*d.* cloth.

TWISS.—ON THE RELATIONS OF THE DUCHIES OF SCHLESWIG AND
HOLSTEIN TO THE CROWN OF DENMARK AND THE GERMANIC CONFEDERATION, and on the Treaty-Engagements of the Great European Powers in reference thereto. By Travers Twiss, D.C.L. F.R.S., Fellow of University College, Oxford, and Advocate in Doctors Commons. 8vo. 6*s.* 6*d.* cloth.

TWISS.—VIEW OF THE PROGRESS OF POLITICAL ECONOMY IN
EUROPE SINCE THE SIXTEENTH CENTURY; being a Course of Lectures delivered before the University of Oxford, in Michaelmas Term 1846, and Lent Term 1847. By Travers Twiss, D.C.L. F.R.S. Professor of Political Economy, and Fellow of University College, Oxford. 8vo. 10*s.* 6*d.* cloth.

URE.—DICTIONARY OF ARTS, MANUFACTURES, AND MINES:
Containing a clear Exposition of their Principles and Practice. By Andrew Ure, M.D. F.R.S. M.G.S. M.A.S. Lond.; M. Acad. N.S. Philad.; S. Ph. Soc. N. Germ. Hanov.; Mulili, etc. etc. 3d Edition, corrected. 8vo. with 1,240 Woodcuts, 50*s.* cloth.

By the same Author,

SUPPLEMENT OF RECENT IMPROVEMENTS. 2d Edition. 8vo. 14*s.* cloth.

VON ORLICH (CAPT.)—TRAVELS IN INDIA,
And the adjacent Countries, in 1842 and 1843. By Capt. Leopold Von Orlich. Translated from the German by H. Evans Lloyd, Esq. 2 vols. 8vo. with coloured Frontispieces, and numerous Illustrations on Wood, 25*s.* cloth.

WALFORD (J. E.)—THE LAWS OF THE CUSTOMS,
Compiled by Direction of the Lords Commissioners of Her Majesty's Treasury, and published under the Sanction of the Commissioners of Her Majesty's Customs; with Notes and a General Index. Edited by J. G. Walford, Esq. Solicitor for the Customs. Printed for Her Majesty's Stationery Office, and published by Authority. 8vo. 10*s.* 6*d.* cloth.

WALKER.—ELEMENTA LITURGICA;
Or, the Churchman's Primer, for the Scholastic Study of the Book of Common Prayer. By G. A. Walker, A.M., of Christ College, Cambridge. New Edition, entirely rearranged and considerably enlarged. Fcap. 8vo. 4*s.* 6*d.* cloth.

WALKER (GEO.)—CHESS STUDIES:
Comprising 1,000 Games actually Played during the last Half Century; presenting a unique Collection of Classical and Brilliant Specimens of Chess Skill in every stage of the Game, and forming an Encyclopædia of Reference. By George Walker. 8vo. 10*s.* 6*d.* sewed.

WARDLAW.—DISCOURSES ON THE PRINCIPAL POINTS OF THE SOCINIAN CONTROVERSY—the Unity of God, and the Trinity of Persons in the Godhead—the Supreme Divinity of Jesus Christ—the Doctrine of the Atonement,—the Christian Character, etc. By Ralph Wardlaw, D.D. New Edition. 8vo. 15*s.* cloth.

WATERTON.—ESSAYS ON NATURAL HISTORY,

Chiefly Ornithology. By Charles Waterton, Esq., author of "Wanderings in South America." With an Autobiography of the Author, and a View of Walton Hall. New Edition. Foolscap 8vo. 8*s.* cloth.

SECOND SERIES. With Continuation of Mr. Waterton's Autobiography. New Edition. Fcap. 8vo. with Vignette by T. Creswick, A.R.A. 6*s.* 6*d.* cloth.

WEBSTER.—AN ENCYCLOPÆDIA OF DOMESTIC ECONOMY;

Comprising such subjects as are most immediately connected with Housekeeping: as, The Construction of Domestic Edifices, with the Modes of Warming, Ventilating, and Lighting them—A Description of the various Articles of Furniture, with the Nature of their Materials—Duties of Servants, etc. etc. By Thomas Webster, F.G.S., etc. etc.; assisted by the late Mrs. Parkes. New Edition. 8vo. with nearly 1,000 Woodcuts, 50*s.* cloth.

WESTWOOD (J. O.)—AN INTRODUCTION TO THE MODERN CLASSIFICATION OF INSECTS; founded on the Natural Habits and comparative Organisation of the different Families. By J. O. Westwood, F. L. S. etc. 2 vols. 8vo. with numerous Illustrations, 2*l.* 7*s.* cloth.

WILBERFORCE (W.)—A PRACTICAL VIEW OF THE PREVAILING RELIGIOUS SYSTEMS OF PROFESSED CHRISTIANS, in the Higher and Middle Classes in this Country, contrasted with Real Christianity. By William Wilberforce, Esq. M.P. for the County of York. New Editions. 8vo. 8*s.* boards. 12mo. 4*s.* 6*d.* cloth.

WILSON.—THE LANDS OF THE BIBLE VISITED AND DESCRIBED,

In an Extensive Journey undertaken with special reference to the Promotion of Biblical Research and the Advancement of the Cause of Philanthropy. By John Wilson, D.D. F.R.S. Honorary President of the Bombay Branch of the Royal Asiatic Society, etc. 2 vols. 8vo. with Maps and numerous Illustrations, 1*l.* 16*s.* cloth.

WILLOUGHBY (LADY)—SO MUCH OF THE DIARY OF LADY WILLOUGHBY as relates to her Domestic History, and to the Eventful Period of the reign of King Charles the First (1635 to 1648). Produced in the style of the period to which "The Diary" refers. New Edition. Square foolscap 8vo. 8*s.* boards; or 18*s.* bound in morocco (*by Hayday*).

WILLOUGHBY (LADY).—SOME FURTHER PORTIONS OF THE DIARY OF LADY WILLOUGHBY, which do relate to her Domestic History, and to the Stirring Events of the latter years of the reign of King Charles the First, the Protectorate, and the Restoration (1648 to 1663). New Edition. Square foolscap 8vo. 8*s.* boards; morocco, 18*s.* (*bound by Hayday*).

WINTER (J. W.)—THE HORSE IN HEALTH AND DISEASE:

Or, Suggestions on his Natural and General History, Varieties, Conformation, Paces, Age, Soundness, Stabling, Condition, Training, and Shoeing. With a Digest of Veterinary Practice. By James W. Winter, M.R.C.V.S.L. 8vo. 10*s.* 6*d.* cloth.

WOOD.—A PRACTICAL TREATISE ON RAILROADS,

And Interior Communication in General; containing numerous Experiments on the Powers of the Improved Locomotive Engines, and Tables of the comparative Cost of Conveyance on Canals, Railways, and Turnpike Roads. By Nicholas Wood, Memb. Inst. Civ. Eng. etc. 3d Edition. 8vo. with Plates and Woodcuts, 31*s.* 6*d.* cloth.

WOODWARD.—ESSAYS AND SERMONS.

By the Rev. Henry Woodward, M.A., formerly of Corpus Christi College, Oxford, Rector of Fethard, in the Diocese of Cashel. New Edition. 2 vols. fcap. 8vo. 14*s.* cloth.

WOODWARD.—A SEQUEL TO THE SHUNAMMITE:

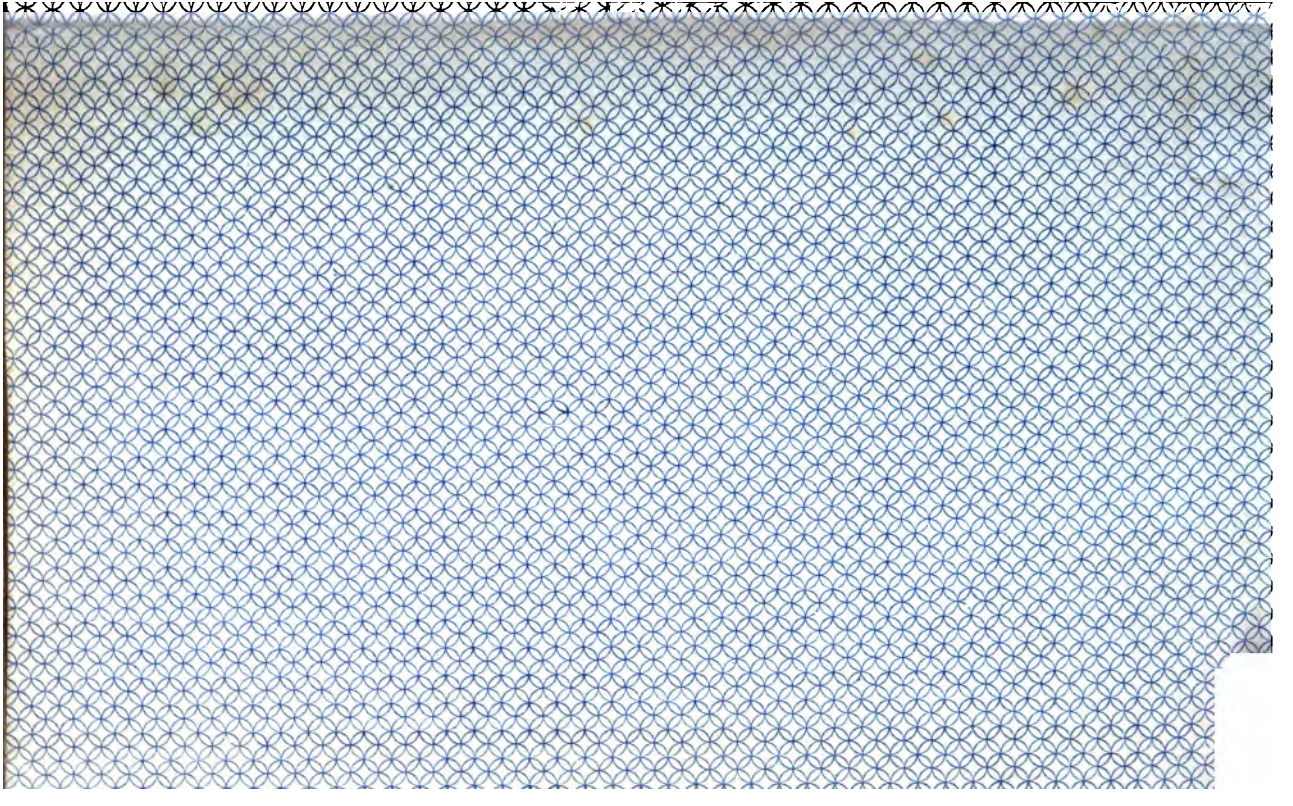
Being a Series of Reflections on 2 Kings iv. 17-35. By the Rev. Henry Woodward, M.A., Rector of Fethard, in the Diocese of Cashel, and formerly of Corpus Christi College, Oxford. Fcap. 8vo. 6*s.* cloth.

ZUMPT (PROF.)—A GRAMMAR OF THE LATIN LANGUAGE.

By C. G. Zumpt, Ph. D. Professor in the University, and Member of the Royal Academy of Berlin. Translated from the 9th Edition of the original, and adapted to the use of English Students, by Leonhard Schmitz, Ph. D., Rector of the High School of Edinburgh; with numerous Additions and Corrections by the Author. New Edition. 8vo. 14*s.* cloth.

[*August* 31, 1843.

London: Printed by M. MASON, Ivy Lane, Paternoster Row.



ESTABLISHED WORKS OF GENERAL INTEREST.

WORKS ON NATURAL PHILOSOPHY.

Sir John Herschel On the Study of Natural Philosophy	1 vol.	6s.
Baden Powell's History of Natural Philosophy	1 vol.	6s.
Sir John Herschel's Treatise on Astronomy	1 vol.	6s.
Sir David Brewster's Treatise on Optics	1 vol.	6s.
Capt. Kater and Dr. Lardner's Treatise on Mechanics	1 vol.	6s.
Dr. Lardner's Treatise on Arithmetic	1 vol.	6s.
Dr. Lardner's Treatise on Heat	1 vol.	6s.
Dr. Lardner's Hydrostatics and Pneumatics	1 vol.	6s.
Dr. Lardner's Treatise on Geometry	1 vol.	6s.
Dr. Lardner & Mr. Walker's Manual of Electricity, &c.	2 vols.	12s.
Prof. Donovan's Treatise on Chemistry.....	1 vol.	6s.
Prof. De Morgan's Treatise on Probabilities	1 vol.	6s.

WORKS ON MANUFACTURES AND THE ARTS.

Domestic Economy, by Prof. Donovan	2 vols.	12s.
Porcelain & Glass Manufactures, by G. R. Porter, F.R.S.	1 vol.	6s.
The Manufacture of Silk, by G. R. Porter, F.R.S.	1 vol.	6s.
The Manufactures in Metal, by John Holland.....	3 vols.	18s.

WORKS ON NATURAL HISTORY.

Swainson On the Study of Natural History	1 vol.	6s.
The Habits and Instincts of Animals, by Swainson ..	1 vol.	6s.
The Classification of Animals, by Swainson.....	1 vol.	6s.
Swainson's Natural History of Quadrupeds.....	1 vol.	6s.
Swainson's Natural History of Birds.....	1 vol.	6s.
Animals in Menageries, by Swainson.....	1 vol.	6s.
Amphibia and Reptiles, by Swainson.....	2 vols.	12s.
The Natural History of Insects, by Swainson & Shuckard	1 vol.	6s.
Shells and Shell Fish, by Swainson.....	1 vol.	6s.
Swainson's Treatise on Taxidermy	1 vol.	6s.
Prof. Phillips's Treatise on Geology	2 vols.	12s.
Henslow's Descriptive and Physiological Botany	1 vol.	6s.

The above works are comprised in

THE CABINET CYCLOPÆDIA, now completed in 133 vols. £39. 10s.

LONDON: LONGMAN AND CO.; AND JOHN TAYLOR.

BOUND BY
WESTLEYS &
CLARK
LONDON